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State Antifragility: An Agent-Based Modeling Approach to Understanding State Behavior

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STATE ANTIFRAGILITY: AN AGENT-BASED MODELING APPROACH TO

UNDERSTANDING STATE BEHAVIOR

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ABSTRACT

STATE ANTIFRAGILITY: AN AGENT-BASED MODELING APPROACH TO UNDERSTANDING STATE BEHAVIOR

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This dissertation takes an interdisciplinary approach to understanding what makes states antifragile and why this matters by constructing a parsimonious, first of its kind agent-based model. The model focuses on the key elements of state antifragility that reside along a spectrum of fragility and transverse bidirectionally from fragile to resilient to antifragile given a certain set of environmental conditions.

First coined by Nicholas Nassim Taleb and applied to economics, antifragility is a nascent concept. In 2015, Nassim Taleb and Gregory Treverton's article in Foreign Affairs outlined five characteristics of state antifragility. This project aims to advance the study of anti-fragility in the context of the nation-state beyond these initial contributions by (1) development of three propensity variables associated with antifragility, (2) a new agent-based model to investigate antifragility, and (3) applying the findings of the model and the propensity score theorizing to two case studies.

This research posits three propensity variables for a state to become fragile, resilient or antifragile. These variables include learning, power conversion, and agility. Cumulatively, these variables comprise a state's capacity for dealing with various stressors in the international environment. The agent-based model in this dissertation captures the behavior of a single state when confronted with a stress in a variety of scenarios, forming an essential building block for future work (hinted at in the case studies) involving the interaction between states. The case

studies show how the propensity variables, and the model results provide the basis for a distinctive and relatively novel evaluation of the historical record involving the history of the United States in and with Iraq, and the evolving great power rivalry between the United States and China, emphasizing the value of taking antifragility seriously in the context of International Studies.

To my family, who always reminds me that there is no sin in trying in failing.

The sin is in having never tried at all.

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This dissertation is dedicated first and foremost to my family. To my children, Candler, Emory, Willoughby, and Hammond. You have witnessed mom at her highest and lowest points throughout this journey, but because of each of you, you never saw her quit. To my husband, Nicholas. Thank you for encouraging me and helping me “ride the lightening”. To my parents, Heyward and Agnes. Your guidance and wisdom have made all of this possible for without my suborn determination, this would have never been completed.

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NOMENCLATURE

A2/AD	Anti-Access Area Denial
APA	American Psychological Association
APEC	Asia-Pacific Economic Cooperation
AQI	Al-Qaeda in Iraq
ASPI	Australian Strategic Policy Institute
BRI	Belt and Road Initiative
CAST	Conflict Assessment System Tool
DIA	Defense Intelligence Agency
DNI	Director of National Intelligence
DoD	Department of Defense
EU	European Union
FSI	Fragile States Index
GDP	Gross Domestic Product
IDF	United States International Development Finance Corporation
IDP	Internally Displaced Persons
IED	Improvised Explosive Device
IID	Independent, Identically Distributed
IIEE	Institute of Industrial Engineers
ISIS	Islamic State of Iraq and Syria
NASA	National Aeronautical Space Association
OECD	Organization for Economic Cooperation and Development

R2P	Responsibility to Protect
PCA	Principal Components Analysis
PLA	People's Liberation Army
RPG	Rocket Propelled Grenades
SCS	South China Sea
UN	United Nations
UNISDR	United Nations International Strategy for Disaster Reduction
US	United States
USAID	United States Agency for International Development
USINDOPACOM	United States Indo-Pacific Command
WHO	World Health Organization
WMD	Weapons of Mass Destructions
WTO	World Trade Organization

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INTRODUCTION

"Some things benefit from shocks; they thrive and grow when exposed to volatility, randomness, disorder, and stressors and love adventure, risk and uncertainty. Yet, in spite of the ubiquity of the phenomenon, there is no word for the exact opposite of fragile. Let us call it antifragile. Antifragility is beyond resilience or robustness. The resilient resists shocks and stays the same; the antifragile gets better."[1]

Antifragility is vitally important because surprising, disorienting, and potentially dangerous things show no sign of ceasing to happen. The twenty-first century is characterized by an international community that is hyper-globalized. The rapid ascent of terrorist organizations that function like nation states, the escalation of the effects of climate change, the emergence of a Fourth Industrial Revolution[2], and instant connectivity to anyone anywhere in the world with the attendant opportunities and risks of global contagion are just a few of the defining characteristics of this new global environment. In this context, challenges can emerge from many quarters, often ones only partially expected. From the September 11, 2001, terrorist attacks through a housing crash not anticipated by bank risk models, to the Covid-19 pandemic and the unprecedented response to it, recent history offers ample grounds for the suspicion that state survival and success depends in part on effective response to such shocks. This hyper-globalized world can be described as a wicked world defined by a wicked learning environment.[3]

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[1] Taleb, Nassim Nicholas. *Fooled by Randomness: The Hidden Role of Chance in Life and in the Markets*. New York, New York: Thomson/Texere, 2004.

[2] https://www.weforum.org/centre-for-the-fourth-industrial-revolution; The First Industrial Revolution used water and steam power to mechanize production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production. Now a Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres. There are three reasons why today's transformations represent not merely a prolongation of the Third Industrial Revolution but rather the arrival of a Fourth and distinct one: velocity, scope, and systems impact. The speed of current breakthroughs has no historical precedent. When compared with previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear pace. Moreover, it is disrupting almost every industry in every country. And the breadth and depth of these changes herald the transformation of entire systems of production, management, and governance.

[3] The term wicked problem originated from design theorists Horst Rittel and Mevin Webber. The term was introduced to draw attention to the complexities and challenges of addressing planning and social policy problems. As described by Rittel and Webber, wicked problems have 10 important characteristics. 1) They do not have a definitive formulation. 2) They do not have a "stopping rule" In other words, these problems lack an inherent logic that signals where they are solved. 3) Their solutions are not true or false, only good, or bad. 4)There is no way to test the solution to a wicked problem. 5) They cannot be studied

That is to say, the rules in this environment are not fixed, nor are they necessarily linear: effective response requires agility, learning, and the ability to convert power resources in smart ways to solve difficult challenges.

The challenges arise at many levels. For instance, the weakening of the Western political model demonstrates that not only are the rules changing, but rivals are seeking to fashion a new political model mirrored in their own values and principles.[4] In 2015, few in the United States might have anticipated that a year or two later the United States government would be consumed by a scandal involving the alleged interference by the Russian government in the United States (US) election, or that in 2021 a mob of citizens mobilized by political rhetoric and propaganda would breach the US capitol building and briefly interrupt the counting of electoral votes. Shocks can come from many directions, and in surprising ways.

As a result of the velocity and magnitude of this change, more low probability-high consequential events are not only occurring but going unanticipated, illuminating the challenges of anticipating or even explaining such events and their consequences. Historical examples of this include the failure to anticipate the conclusion of the Cold War or the rise of non-state actors to prominence in the latter half of the twenty-first century and explanation of a non-state actor, Al Qaeda in Iraq, demonstrated a temporary advantage over the United States military in Iraq during the Iraq War, as demonstrated by the case study in Chapter 5.

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through trial and error. Their solutions are irreversible. 6) There is no end to the number of solutions or approaches to a wicked problem. 7) All wicked problems are essentially unique. 8) Wicked problems can always be described as the symptom of other problems. 9) The way a wicked problem is described determines its possible solutions. 10) Planners, that is those who present solutions to these problems, have no right to be wrong. Drawn from the term wicked problem-a problem that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize- a wicked world is one comprised of wicked problems.

[4] Jones, Bruce, and Torey Taussig. "Democracy & Disorder: The Struggle for Influence in the New Geopolicies." Brookings, February 2019. https://www.brookings.edu/research/democracy-disorder-the-struggle-for-influence-in-the-new-geopolitics/.

Furthermore, the means by which states are competing are more dynamic and complex. For example, the complexity and dynamism with which China and Russia seek to forge a new global order is palpable. "Both Russia and China, using different means and different strengths, seek to achieve three objectives: to develop military and economic spheres of influence in their regions; to weaken democratic institutions and norms that challenge their own internal legitimacy; and to diminish Western dominance of the international order."[5] In this struggle for influence in new geopolitics, "the West's response has been insufficient to the challenge" though there may be structural challenges present in the People's Republic of China that may reveal themselves to be weaknesses with time and is later explored in Chapter 6 is the great power competition between the United States of America and the People's Republic of China in the Indo-Pacific.[6]

Philip Tetlock's most famous research project began in 1984, focusing understanding which group of political pundits would turn out to be right about the end of the Cold War.[7] Some argue that what most did not recognize until it was too late was the level of social and institution decay that had occurred within the Soviet Union. Others posit differing explanations for the dramatic transformation that occurred in international relations. Tetlock's monitoring of pundit's predictions revealed a startling result. All were wrong in their predictions. In the end, scholars from all theoretical schools of thought were confounded by the consequential significance of the role inherent characteristics of a state (the fragility of the Soviet Union) played in bringing an end to the Cold War and found it difficult to reconcile with the fact that it was the implementation of a series of internal reforms enacted by Mikhail Gorbachev that

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[5] Jones and Taussig, Democracy & Disorder: The Struggle for Influence in the New Geopolicies.
[6] Jones and Taussig, Democracy & Disorder: The Struggle for Influence in the New Geopolicies.
[7] Tetlock, Philip E. "Good Judgement in International Politics: Three Psychological Perspectives." *Political Psychology* 13, no. 3 (September 1992): 517–39. https://doi.org/10.2307/3791611.

reigned supreme.[8] The point here is that shocks like the dissolution that overtook and evaporated the Union of the Soviet Social Republics (USSR) can be hard to anticipate. They happen. States have to then respond effectively to them in order to project interests or more consequentially, survive.

As noted at the very outset, the concept of antifragility is important precisely because of the challenges of anticipating shocks and the need to effectively survive them. Through the turbulence of unpredicted events, some states learn, or are learning, to navigate these changes better than others. I argue that there are commonalities (propensity variables) that bind these states together, defined by a set of characteristics that distinguish them from others who are unable to navigate these changes well. These states are more *agile* than others in traversing uncertainty. They are better able to *convert power* in a complex environment, and most critically, they are better at *learning* from their experiences and at learning how to do all three of the above better. In the face of challenges or shocks, some states adapt so effectively that they can take advantage of the challenges to become stronger. These are the antifragile states. Other states manage to merely maintain a status quo (resilient states) and others weaken or even fail (fragile states).

The primary research question of this dissertation is: Why are some states more antifragile than others, and what difference does this make? I answer the first part of the question by identifying the three propensity scores alluded to above: agility, power conversion, and learning. I then develop an agent-based model of a state facing shocks to explore the difference antifragility makes for state survival and state power, and to explore the links between challenging environments and the development or maintenance of antifragility. Finally, two case

[8] Gaddis, John Lewis. *The Cold War: A New History*. New York, NY: Penguin Group, 2007.

study chapters show how an analysis of that centers on fragility and antifragility as guided by both the model and the propensity variables can illuminate and reinterpret world events in ways that promise to provide both increased insight and increased ability to predict.

The term antifragile comes from research of Nassim Taleb used to describe a category of things that not only gain from chaos but depend on it to survive and flourish. In his 2012 book, *Antifragile: Things that Gain from Disorder*, Taleb offers the following definition of antifragility:

> Some things benefit from shocks; they thrive and grow when exposed to volatility, randomness, disorder, and stressors and love the adventure, risk and uncertainty. Yet in spite of the ubiquity of the phenomenon, there is no word for the exact opposite of fragile. Let us call it antifragile. Antifragility is beyond resilience or robustness. The resilient resists shocks and stays the same; the antifragile gets better.[9]

The idea that people, systems, or even states might gain from disorder is a counterintuitive concept, and the existing scholarship in International Relations and Political Science mostly ignores it. In the Web of Science only a handful of articles (11 of more than 300) citing Taleb's 2012 book are in the field of International Relations, for instance.[10]

Although fragility and resilience receive attention in these fields, antifragility remains a largely foreign concept. Presently, the literature focuses primarily on examining state fragility and resilience in the form of quantitative indices that measure and rank states based on a certain set of criteria; however, these indices quantifying fragility and resilience do not measure or theorize about anything beyond resilience. That is, they do not explicitly consider the possibility that some states may benefit from disorder.

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[9] Taleb, Nassim Nicholas. *Antifragile: Things That Gain From Disorder*. New York, NY: Random House, 2014.
[10] Search conducted 6/2/2021 using Web of Science.

The current theoretical paradigms that dominate the field of International Relations such as realism, liberalism, and constructivism have failed to anticipate and explain some of our biggest changes in international relations. In some cases, each has promoted ideas and beliefs contrary to those changes. For example, the end of the Cold War is arguably one of the most important events of the twentieth century that International Relations scholars universally failed to predict, as noted above. Accepted academic predictions on how the Cold War would end centered on a nuclear exchange between the United States and the Cold War did not materialize.

Most recently, the conceptual difficulties of Realism have become evident after the September 11, 2001, terrorist attacks against the United States of America. As Jack Snyder writes in his Foreign Policy article, *One World, Rival Theories*, “It is harder for the normally state-centric realists to explain why the world’s only superpower announced a war against al Qaeda, a non-state terrorist organization how can realist theory account for the importance of powerful and violent individuals in a world of states?“[11] Limited theoretical frameworks might even generate fragility by blinding states and individuals to potential challenges or threats, or leading to inappropriate responses to threats when experienced. As explored in the Iraq case study (Chapter 7), the belief that a few ex-Saddam-regime ‘dead enders’ did not constitute a serious insurgent threat arguably delayed effective learning and reduced agility and power conversion, rendering the US war effort from 2003 through 2006 more fragile than it would otherwise have been.

With these shortcomings in mind, the introduction of a new concepts such as antifragility may have many benefits. Most critically, the addition of antifragility into our scholarship, nested in the theoretical home of Realism, helps both scholars and practitioners better understand the

[11] Snyder, Jack. “One World, Rival Theories.” Foreign Policy, October 26, 2009. https://foreignpolicy.com/2009/10/26/one-world-rival-theories/.

organization and mechanism behind state behavior, and the ways in which states adapt successfully or unsuccessfully to the challenges and problems they encounter over time.

PURPOSE OF THE RESEARCH AND DESIGN

As already indicated, this research seeks to answer the question *why are some states more antifragile than others, and what difference does this make*? This research will answer the first part of this question by identifying the critical characteristics of state antifragility in terms of three propensity variables and the second part by modeling state antifragility using agent-based modeling and applying model results and the propensity score concepts to a pair of case studies. This research seeks to model the behavior of a state during a period of stress by characterizing the structure of antifragility and the causes or factors that move a state along the state fragility spectrum.

DISSERTATION DESIGN

To begin to answer the research question, this dissertation begins by providing a literature review of the historical and current state of research regarding fragility, resiliency, and antifragility in Chapter 2. This chapter focuses on understanding the qualitative and quantitative differences among the term's fragility, resiliency, and antifragility by pulling from an array of interdisciplinary literature from biology, psychology, and sociology. Additionally, this chapter narrows down the focus of my application of antifragility in the International Relations literature to find an application of antifragility in the realist paradigm as it pertains to power. Moreover, current models of antifragility are examined to establish a baseline of research on antifragility through the use of modeling and simulation.

Chapter 2 begins the development of the key theoretical concepts. In order to answer the question *why some states are more antifragile than others,* the first phase of inquiry focuses on identifying what characteristics of a state give rise to antifragility. While indices such as the aforementioned fragile states indexes focus on discrete, quantifiable variables, they do not include the concept of antifragility explicitly. Nassim Taleb and Gregory Treverton's 2015 Foreign Affairs Article, *The Calm Before the Storm: Why Volatility Signals Strength*, established a preliminary list of five indicators of state fragility on a scale explicitly intended to include antifragility -- governance type, economic diversity, debt to leverage, political variability, and history of surviving past shocks, and while this work is an important milestone for the introduction of antifragility to international relations, it falls short of nesting itself intellectually into our theories of International Relations.

Guided by other parts of the literature on antifragility, this dissertation refines Taleb and Treverton's five variables into three original factors called *propensity factors* that include *learning*, *agility*, and *power conversion*. Each is examined and discussed in greater detail in Chapter 2. This includes in depth understanding of what factors are most critical to scholars if they are to understand *under what conditions* states traverse along the spectrum from fragility to antifragility.

The propensity variables presented in this dissertation restructure Taleb and Treverton's five characteristics of state antifragility into three factors in Table 1 below.

Table 1: Translation of Taleb and Treverton's Variables to Propensity Variables

Propensity Variables	Source	Defined As…
Agility	Taleb & Treverton (2015)	Concentrated decision making Political variability
Power Conversion	Taleb & Treverton (2015)	Economic Diversity Debt to Leverage Ratio
Learning	Taleb & Treverton (2015)	History of Surviving Past Shocks

Rather than setting hard bounds by which states are defined as antifragile, fragile, or resilient, the reconsideration of these variables into propensity variables frames Taleb and Treverton's characteristics such that they can be viewed has having the propensity to give rise to movement along the fragility spectrum rather than a black or white, binary choice of whether or not they do or do not cause movement along that spectrum. In other words, framing the variables this way allows scholars to view a given a set of characteristics and understand under what conditions might a state become fragile, resilient, or antifragile.

In addition to the examination of the propensity variables, an assessment of where the potential relationships between antifragility and the theoretical paradigms of International Relations is included in the discussion. In particular, Realism is identified as the theoretical home for this new concept.

The next chapters, beginning with Chapter 3 develop and present an agent-based model of state antifragility to provide the first part of my answer to the question of what difference antifragility makes. Chapter 3 provides discussion on the background and rationale for choosing to employ agent-based modeling. The use of agent-based modeling is particularly well suited to allow researchers to explore this question for several reasons. A model is an abstracted description of a process, object, or other event. It exaggerates certain aspects at the expense of others, focusing on the aspects we are most interested in.[12] In the case of this dissertation, the model presented in Chapter 4 is a theoretical one based on notional data, which brings along its own set of benefits explored later in the dissertation.

A simulation is an applied methodology that can describe a behavior of that system using either a mathematical model or a symbolic model. In other words, a simulation is the imitation

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[12] Sokolowski, John A., and Catherine M. Banks, eds. *Principles of Modeling and Simulation: A Multidisciplinary Approach*. Hoboken, NJ: Wiley, 2009.

of the operation of a real-world process or system over a period of time (Sokolowski and Banks, 2009). Agent-based modeling is the idea that the world can be usefully modeled using computer-generated agents, an environment, and a description of agent-agent and agent-environment interactions.

Axelrod (1997) described agent-based modeling as a third way of doing science. That is, the two traditional ways of doing science are induction, inferring from particular data to a general theory, and deduction, reasoning from first principles to a general theory. This third way, as Axelrod describes, is referred to as generative. That is using first principles to generate a particular set of data that can create a general theory, which can allow for integrative understanding. From this, if one knows the first principal rules, then an aggregate pattern can be determined. Typically, this is a difficult process, but agent-based modeling provides us a way to understand this. Potentially, agent-based modeling allows the user to know the aggregate pattern up front and then figure out the individual level rules.

Computational agent-based modeling has several additional advantages over other methodologies such as formal equation-based modeling or system dynamics modeling. Agent based models are bottom-up processes rather than top down. Agent based models can be built from analytical models and can complement equation-based models. While system dynamics modeling embraces a system-level approach to thinking about the world, it often overlooks the individual-level representation. There are also limitations to agent-based modeling including high computational costs, many free parameters and requirements concerning individual-level behavior knowledge.

Toolkits for agent-based modeling are relatively new. Tracing the lineage of agent-based modeling toolkits takes us back to the early 1990s SWARM. Repast came from the Aragon

National Lab, has been around since the early 2000s. The Brookings Institute is responsible for the creation of Ascape which was famously used for Joshua Epstein and Robert Axtell's Sugarscape models. The model in this project was simulated using Netlogo. Designed by Uri Wilensky at Northwest University, Netlogo is the most widely used program in the agent-based modeling environment.

Despite its relative newness, agent-based modeling has made significant contributions in the social sciences. Thomas Schelling's Model of Segregation is one of the first agent-based models to explore important social issue or racial segregation.[13] Today the wide application of agent-based models can be seen across a variety of fields including policy modeling and traffic optimization (Grether et al., 2010) financial crises (Sornette, 2003) and epidemics (Pastor-Satorras and Vespignani, 2001).[14][15][16]

Chapter 4 presents the construction of the model in detail by breaking down the model into three focus areas-the agent, the environment, and the interaction between the agent and the environment. The second half of the chapter focuses on the ways in which experiments of the model were constructed to answer two questions. First, how is antifragility important for state survival, and second, what type of world is best for state survival and maintaining antifragility? The agent-based model presented in this dissertation is the first of its kind to formalize a relationship among these propensity variables to yield a model of the process by which states become fragile, resilient or antifragile. To summarize the model, a single agent (state) interacts

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[13] Schelling, Thomas C. "Dynamic Models of Segregation." *Journal of Mathematical Sociology* 1, no. 2 (1971): 143–86. https://doi.org/10.1080/0022250X.1971.9989794.

[14] Grether, Dominik, Benjamin Kickhöfer, and Kai Nagel. "Policy Evaluation in Mulitagent Transport Simulations." *Transportation Research Record 2175*, no. 1 (January 2010): 10–18. https://doi.org/10.3141/2175-02.

[15] Sornette, Didier. *Why Stock Markets Crash Critical Events in Complex Financial Systems*. Princeton, NJ: Princeton University Press, 2003.

[16] Pastor-Satorras, Roumaldo, and Vespignani Alessandro. "Epidemic Spreading in Scale-Free Networks." *Phys. Rev. Lett.* 86, no. 14 (April 2, 2001): 3200–3203. https://doi.org/10.1103/PhysRevLett.86.3200.

with shocks (red patches in the Netlogo visualization) throughout the simulation environment at random. States are endowed with a set of characteristics, informed by the literature and the three propensity variables. When the agent interacts with a shock, a series of internal processes by the state is undertaken. Briefly, as a result of these processes, antifragile states become stronger, resilient states return to their initial status, and fragile states become weaker. In some of the simulations, interaction with shocks may also lead to transformation of the state as fragile states learn to become more resilient or even antifragile, or antifragile states forget and become merely resilient or even fragile. Greater detail regarding the design of the model can be found in Chapter 4.

Overall, the model results which are analyzed in Chapter 5 provide a basis for insights concerning the difference antifragility makes. The results of the simulation model demonstrate how critical antifragility can be to the survival and success of states and other entities including people, international organizations, and non-governmental organizations. Furthermore, by understanding not only what conditions produce antifragile states, but what conditions are necessary to maintain antifragility, states can begin to fashion their governance systems such that they are posed to produce antifragile outcomes.

The case studies are presented in Chapter 6 and Chapter 7 to highlight areas where the concept of antifragility might have enhanced our explanatory power of these case studies and even helped us foresee their unanticipated outcomes. In the case of enhancing our explanatory power, Chapter 6 presents the case study of the most recent Iraq War is viewed through the lens of antifragility, focusing on a deficiency in learning on behalf of the United States against an increasingly formidable, insurgent adversary. In the case of foreseeing unanticipated outcomes, Chapter 7 pivots to the current great power competition playing out in the Indo-Pacific region between the United States and China. Both reveal the importance of learning, agility, and power conversion (along with the exposure to prior shocks so crucial in the World B results of Chapter 5) as critical components of antifragility and highlight the value of the simulation model in identifying patterns of behavior that match the case study phenomena.

Finally, Chapter 8 provides commentary on future areas of work and improvements for the model along with concluding thoughts on antifragility. The concluding chapter helps set an agenda for including thinking about antifragility in International Relations.

RATIONALE, SIGNIFICANCE, AND CONTRIBUTIONS TO THE EXISTING LITERATURE

This dissertation contributes to both the theoretical and methodological components of International Relations. Introducing the concept of antifragility into the theoretical literature in International Relations is new and novel. To date, little has been written on the subject of antifragility, and even less on antifragility as it applies to states in the international system (Ani, 2014, Taleb and Treverton, 2015, Basaran, 2013). Nassim Taleb (2014) first introduced the concept in his book *Antifragile: Things that Gain from Disorder*, where he focuses on risk, uncertainty, and decision making in risky, uncertain conditions. Building upon this concept, Joost Platje (2015) examined the relevance of antifragility for sustainable development and organizational sustainability, and Markey-Tower (2018) further applied antifragility in the context of institutional economics.

Conversely, there is a robust, well-established collection of literature on the fragility of states, and though fragile states are well saturated discussion in International Relations, this dissertation contributes to the literature on fragile states in a number of ways, too. First, Taleb and Treverton's antifragility concept is introduced into the literature on International Relations by including antifragility in the dialogue on state fragility (Taleb and Treverton, 2015) and thereby expanding the possibility of state outcomes. Until this dissertation, scholars have primarily considered states to be on a continuum between two states-fragile or resilient (Fragile States Index, 2019). This scholarship has begun to move away from the fragile end and more towards the resiliency end. For example, these types of dialogues have permeated into the policy realm as states are now increasingly focusing on resiliency goals and structures (United States National Security Strategy, 2017, United States Department of Homeland Security's Quadrennial Homeland Security Review, 2014); however, the integration of antifragility into the discourses, refocuses attention of states from stress mitigation, stress reduction, and stress avoidance to now exploring how states might embrace stress and even prosper from stress. This recalibration of perception becomes increasingly important to states as the complexity of the international system increases and the potential consequences of missteps intensify.

Secondly, antifragility is a multiscalar concept that serves two main purposes. First, it can be used to supplement our traditional theoretical constructs. Chapter 6 and Chapter 7, for example, present a series of case studies whereby antifragility, or some subcomponent thereof, can help elucidate the processes whereby some states and other organizations successfully surmounted challenges and became better while others failed to conquer similar challenges. This lens with which to view and explain these theoretical anomalies opens the door to new insights and understandings of often overlooked or previously misunderstood events. Furthermore, antifragility is multiscalar in that it can be applied horizontally across our various theoretical schools while also vertically applicable to various subdisciplines in International Relations. Horizontally, antifragility can be applied to the various subdisciplines of International Relations for thinking about areas such as financial systems, security arrangements, and foreign policy.

Vertically, antifragility can be applied at all levels of analysis within International Relations, including the system, the state, and the individual.

LITERATURE REVIEW

This chapter has two primary purposes. The first purpose is definitional: to describe the characteristics associated with fragile, resilient, and antifragile entities, with a particular focus on this definition in the context of states. This part of the chapter examines the origins of the terms fragility, resilience, and antifragility from an interdisciplinary perspective, with a primary focus on antifragility. With this continuum from fragile to antifragile defined, the second purpose is to synthesize the literature on the causes of antifragility in the context of literature on state power and learning to develop an answer to the question of what makes a state antifragile: what characteristics can (or could) help a state move beyond mere resilience to a condition in which it gains (at least in the longer term) from disorder (at least from modest levels of disorder). This synthesis focusses upon the identification of three propensity variables: agility, power conversion, and learning that should help a state become antifragile.

In order to better understand the meaning of antifragility, how it might be applied to states, and how this literature informs the model instantiation in this dissertation, it is important to first understand how states are described and quantified from the terms that currently exist, namely as resilient states and fragile states. The first two sections focus on what it means to be a fragile state or resilient state. The fragility or resiliency of a state in the international system is primarily determined and quantified through indices such as the Fragile States Index (FSI) and the Organization for Economic Cooperation and Development (OECD) Index. While these indices are useful, they do not even attempt to capture any measure beyond that of resilience, namely antifragility. This gap in the literature is important because it fails to explain or even conceptualize instances whereby states improve after having experienced some stressor or shock.

What makes a state antifragile? The next goal of this chapter is to synthesize the literature on antifragility in the context of states to identify core propensity variables that lead to state antifragility. Given the central role of Nassim Taleb in initiating the study of antifragility, there is a major focus on Taleb's work in this section, but I also discuss the interdisciplinary work of a number of other authors who have made significant contributions to our understanding of state antifragility. In addition to his original work on the antifragile Nassim Taleb co-authored a piece in *Foreign Affairs* with Gregory Treverton, which was the first attempt at applying the concept of antifragility to states and International Relations. While Taleb and Treverton's foundational ideas serve as a cornerstone for antifragility work in International Relations, the authors' indicators of state antifragility fall short in that they do not describe the relationships among the variables so that others may understand how each works in concert with one another and with the environment to produce fragile, resilient, or antifragile outcomes. I argue that we can abstract from the literature three core propensity variables: agility, power conversion, and learning. States with higher levels of these variables are more antifragile. This is because states which are more agile will be better able to sense challenges, and more effectively able to respond and adapt to them, states with higher levels of power conversion will be better able to absorb shocks and marshal the appropriate power resources to respond to them, and states that are better at learning will be better able to adapt their actions and strategies to take advantage of and effectively respond to shocks.

FRAGILE: HANDLE WITH CARE

Fragile is an adjective often used to describe objects that are easily broken, shattered, or damaged. A fragile object's vulnerability lies in its delicate composition and is typically coupled with an environment that is characterized by unpredictability and turbulence. As a result, the state of being fragile is a dynamic and one that ebbs and flows with changes in both the composition of the entity and its surrounding environment. That is to say that objects, persons, or systems may begin as fragile and metamorphosize to a more resilient state over time and vice versa, either because of changes in the environment, or changes in the inherent properties of the object.

States, societies, economies, and businesses have all been labeled "fragile." In fact, some powerful, seemingly resilient empires met their demise after descending into what can be described as a state of fragility. For example, historians note that the Roman Empire disintegrated when met with the strain of the invasions by the Barbarian tribes, population decline, degradation of institutions, loss of military capacity, and economic troubles.[17] Similarly, the Ottoman Empire withered during the late nineteenth and early twentieth century after a long decline in vigor and power, a series of internal reforms, military overhaul, and the defeat of the Central Powers in World War I, which resulted in the partitioning of the Ottoman Empire by Allied forces.[18] Each empire's transition from one state of being to another (resilient to fragile in both cases) resulted from exposure to both internal stressors (composition) and external stressors (environment). They ceased to be effective at learning how to effectively respond to challenges, they became less and less agile in their ability to address threats and respond flexibly to them, and their ability to convert the latent power and resources of their territories into effective and smartly applied power degraded substantially.

In another example focused on business enterprises, fragility might also arise as the result of a changing environment. Opening its doors in 1879, F.W. Woolworth Company was one of

[17] Andrews, Evan. "8 Reasons Why Rome Fell." History, A&E Television Networks, January 14, 2014. https://www.history.com/news/8-reasons-why-rome-fell.
[18] History.com Editors, ed. "Ottomon Empire." History. A&E Television Networks, November 3, 2017. https://www.history.com/topics/middle-east/ottoman-empire.

the pioneers of the five-and-dime stores in America, but by the mid 1800s and early 1900s, more affluent Americans expanded their tastes, and with it a new model of stores called the department store began to pop up in cities such as New York and Chicago.[19] Although it dominated the discount sector through the first half of the twentieth century, F.W. Woolworth Company eventually "collapsed under its own weight" when it attempted to expand beyond its five-and-dime discount roots and move toward the department store model.[20] Generally speaking, the F.W. Woolworth Company attempted to transform itself into something it was not, influenced by the changing times and external environment, ultimately succumbing to its fragility. The store did not effectively learn how to adapt, and its attempt to shift strategy lacked agility. Ironically, in a poorly advised effort to become what it wasn't, it abandoned a business niche that remains viable today, as exemplified by the success of Dollar Tree and its competitors.

Whether one is referring to fragile objects, systems, or people, fragility results from the union of the composition of each object, person, or system and the environment surrounding that object, person, or system. In turn, this causes others to place a value judgement of "fragile" on the person, object, or system; therefore, it can be said that fragility is subjective and relative to its surrounding environment and the type of stress it encounters.

To demonstrate the relativity of this term, take the example of an heirloom table. An heirloom table might not be particularly fragile with respect to ordinary, daily household use, but packaged in moving crates traveling sixty-five miles per hour in a moving van traveling across the United States with varying road conditions, its ability to survive might be impacted. The United States service member who spends quiet nights at home reading conducts him or herself

[19] Meyer, Susan. "The History and Evolution of Retail Stores: From Mom and Pop to Online Shops." Big Commerce. Accessed 2020. https://www.bigcommerce.com/blog/retail/#what-is-retail.
[20] Robinson, James. "Woolworths: The Rise and Fall of the Department Store Empire." The Guardian, November 19, 2008. https://www.theguardian.com/business/2008/nov/19/woolworths-retail-department-stores

in accordance with social norms, until suddenly he or she encounters a loud noise. Under these conditions, the trauma of prior combat might be brought to the forefront of the service member's reality, causing an abnormal response known as post-traumatic stress disorder (PTSD). In both of these examples, by changing the composition of both the heirloom table (fortifying it with reinforcing screws) and the service member (behavioral and cognitive therapy), the same environments of the moving truck and loud noise might be mitigated and improved, causing each to become resilient to the environments and stressors that once made them fragile.

With this literature in mind, a single state (*the agent*) presented in the model in Chapter 4 is endowed with a variety of internal characteristics and is run through a series of environments that vary in terms of volatility (*number of shocks* in the environment) and the intensity of the stressors, with the parameters for each variable discussed in greater detail in Chapter 4. In doing so, the importance of the discussion on composition and environment discussed in this chapter is captured in the model. When the state has the characteristic of being fragile, encounters with a stressor or shock leads to a long-term reduction in the performance of the state: like our cross-country-trekking heirloom table, it may never be quite the same.

RESILIENCY: NO BETTER, NO WORSE

While the literature on antifragility may be sparse, the literature on resilience is voluminous and integrated into an array of fields of study, with each possessing its own variation on the definition of the term. According to the American Psychological Association (APA), resiliency is defined as "the process of adapting well in the face of adversity, trauma, tragedy, threats or even significant sources of stress."[21] According to others, resilience means "the ability

[21] Southwick, Steven M, George A Bonanno, Anne S Masten, Catherine Panter-Brick, and Rachel Yehuda. "Resilience definitions, theory and challenges: interdisciplinary perspectives" *European Journal of Psychotraumatology* 5, no. 1 (October 1, 2014). https://doi.org/10.3402/ejpt.v5.25338.

to withstand or recover quickly from difficult conditions" (Fletcher and Sarkar, 2013; Robertson et al., 2015).[22] Ecological resilience, for example, refers to "the ability of an ecosystem to maintain key functions and processes in the face of stresses or pressures, by resisting and then adapting to change."[23] [24] According to the United States Department of State, resilience is defined as "the ability to adapt and manage change effectively, be creative in the midst of change, and foster individual, family, community, and workplace team resilience in healthy productive ways."[25]

Regardless of their origin, there appear to be two commonalities to all these definitions. First, as already described in the context of our examination of the fragile, a stress or disturbance is present. That is the person, ecological system, or state must be subjected to some stress or disturbance. But the way the resilient responds is different. The second is the ability of some entity to not only survive that stress but adapt to that stress well. That is to say, the entity must possess the ability to deal with the stress or disturbance in such a way that it does not break or die (fragile) but rather returns to its original state after experiencing a stress or disturbance, given some passage of time. That is not to say that during this period of stress, the entity may not deteriorate or even lose capabilities. These consequences are fully anticipated, rather it is after the stress or disturbance has subsided, the entity appears and functions as it previously did prior to experiencing the stress.

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[22] Liu, Haoran, Chenfeng Zhang, Yannan Ji, and Li Yang. "Biological and Psychological Perspectives of Resilience: Is It Possible to Improve Stress Resistance?" *Frontiers in Human Neuroscience* 12 (August 21, 2018). https://doi.org/10.3389/fnhum.2018.00326.
[23] Nyström, Magnus, and Carl Kolke. "Spatial Resilience of Coral Reefs." *Ecosystems* 4 (August 2001): 406–17. https://doi.org/10.1007/s10021-001-0019-y.
[24] Holling, C S. "Resilience and Stability of Ecological Systems." *Annual Review of Ecology and Systematics* 4 (1973): 1–23. https://www.jstor.org/stable/2096802.
[25] "Resilience." U.S. Department of State. Accessed 2018. https://www.state.gov/resilience-cefar/.

The simulation model described and developed in Chapters 3 and 4 reflects these core characteristics of the response of fragile and resilient states to stress. The presence of stressors (*shocks*) is included in the model, with varying degrees of frequency and intensity and two of the available types of states are those possessing resiliency and fragility. Unlike fragile states, resilient states which encounter a shock recover to their original level of performance. Equally important from this discussion on resiliency is the notion of adaptation and the speed with which recovery occurs. This characteristic was captured in the model by endowing the agent with a recovery period (*recoveryperiod*) by which the agent deals with the stress in such a way that it does not fail but actively recovers with the passage of time.

Prior to understanding what makes a state resilient, it is important to distinguish between resiliency and robustness, and how the two are conceptually different. Resilience can be defined as the ability to return to normal operations over an acceptable period of time, post-disruption.[26] Additionally, resilience focuses on understanding the ability of systems and organizations to persist over time against external shocks. Since, resilience means to bounce back, it's based on an equilibrium-and response-based understanding.[27] That is to say, resilience is reactive and is measured and identified as such after the shock or perturbation has occurred.

Robustness refers to strength and effectiveness, even in adverse conditions.[28] The more robust a system is the less its performance is affected by the disruptions or input changes. In other words, robustness refers to "the ability to withstand or survive external shocks, to be stable in spite of uncertainty, so it is about the ability to maintain functionality in the face of shocks or

[26]Brandon-Jones, Emma, Brian Squire, Chad W. Autry, and Kenneth J. Petersen. "A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness." *Journal of Supply Chain Management* 50, no. 3 (March 24, 2014): 55–73. https://doi.org/10.1111/jscm.12050.

[27] Capano, Gilberto, and Jun Jie Woo. "Resilience and Robustness in Policy Design: a Critical Appraisal." *Policy Sci*, January 5, 2017. https://doi.org/10.1007/s11077-016-9273-x.

[28] Baker, Jack W., Matthias Schubert, and Michael H. Faber. "On the Assessment of Robustness." *Structural Safety* 30, no. 3 (May 2008): 253–67. https://doi.org/10.1016/j.strusafe.2006.11.004.

disturbances."[29] Robustness is proactive and is measured and identified during the shock or perturbation period, not after.

Overall, discussions of robustness and resilience creates a springboard for diving into a discussion on antifragility. Nassim Taleb, by virtue of his definition of antifragility, asserted this much when he wrote, "antifragility is beyond resilience or robustness."[30] Specifically with regard to discussions of robustness and resilience in International Relations, two common themes emerge. First, there is a tendency to treat resilience and robustness are as interchangeable or synonymous, despite them being conceptually distinct. Given the conceptual differences between the two, this dissertation focuses on resilience, not robustness. Second, literature on resilience and robustness focus on measures of preparedness in order to mitigate or temper the effects of a shock's magnitude in order to maintain the functionality and security (i.e., survival) of the state. This is evidenced by papers such as Christian Fjäder's piece, *The nation-state, national security and resilience in the age of globalization,* whereby he focuses on resilience as a strategy to meet the challenges governments have in the provision of security in a globalized world.[31] According to the work of David Stark, resilience in Fjäder's paper focuses on the *preparedness* of the state to challenges brought forth by globalization.[32] Antifragility focuses on not mitigating the effects of shocks, but rather how to benefit from the shock in the long run.

Nonetheless, it should be clear from this discussion that neither resilience nor robustness fully encompasses the concept of antifragility. Both involve ability to absorb shocks and preserve or rebound to previous functionality. Antifragility goes further – it is the ability to get

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[29] Capano, Gilberto, and Jun Jie Woo. "Resilience and Robustness in Policy Design: a Critical Appraisal." *Policy Sci*, January 5, 2017. https://doi.org/10.1007/s11077-016-9273-x.
[30] Taleb, Nassim Nicholas. *Fooled by Randomness: The Hidden Role of Chance in Life and in the Markets*. New York, New York: Thomson/Texere, 2004.
[31] Fjäder, Christain. "The Nation-State, National Security and Resilience in the Age of Globalisation." *International Policies, Practices and Discourses* 2, no. 2 (May 14, 2014): 114–29. https://doi.org/10.1080/21693293.2014.914771.
[32] Stark, David. "On Resilience." *Social Science* 3, no. 1 (February 10, 2014): 60–70. https://doi.org/10.3390/socsci3010060.

better as a result of shocks. It should be noted that the two concepts are conflated in the literature on resilience in international relations, despite their conceptual distinctions.

What makes for a resilient state? Recent years have seen increased emphasis on this question in International Relations. With states as the organizing structure by which decisions are made and actions taken in order to temper anarchy (Realism), a recent pivot towards an emphasis on becoming a resilient state seems to have taken root. For instance, the United States Department of Homeland Security (DHS) recognized resilience in the 2014 Quadrennial Homeland Security Review which established a series of goals and objectives in the areas of critical infrastructure, global movement, supply chain systems, and cyberspace. Correspondingly, the 2017 National Security Strategy also incorporates resiliency into its doctrine when it states "that we must enhance our resilience-which includes the ability to withstand and recover rapidly from deliberate attacks, accidents, natural disasters, as well as unconventional stresses, shocks and threats to our economy and democratic system."[33] Finally, as noted above the United States Department of State followed suit and took notice of resiliency defining it as "the ability to successfully adapt to stressors, maintaining psychological well-being in the face of adversity," noting that resilience requires additional characteristics such as adaptability, flexibility, experience, and practice.[34]

International organizations, too, are taking an active interest in resiliency. DARWIN is a European Union (EU) funded research project under the Horizon 2020 research program that focuses on improving response to expected and unexpected crises affecting critical society structures during natural disasters (e.g., flooding, earthquakes) and man-made disasters (e.g.,

[33] "Resilience." U.S. Department of Homeland Security, January 25, 2021. https://www.dhs.gov/topic/resilience.
[34] "Resilience." U.S. Department of State. Accessed 2018. https://www.state.gov/resilience-cefar.

cyber-attacks).[35] Hoping to directly impact the safety of European citizens during times of crisis and disaster in the future, DARWIN aims at developing European resilience management guidelines. In the same fashion, the United Nations program turned the concept of resilience into a central vehicle for its worldwide program on disaster risk reduction.[36] The United Nations International Strategy for Disaster Reduction (UNISDR) serves as "the focal point in the United Nations system for the coordination of disaster reduction and to ensure synergies among the disaster reduction activities of the United Nations system and regional organizations."[37] By integrating the concept of resilience into their work, they are providing a sense of direction in international negotiations by providing a goal of resiliency.

Some might object that much of what Taleb (and by extension this dissertation) seek from the concept of antifragility is already encompassed in some of the definitions of resilience. Perhaps one might argue that Taleb's claim already quoted twice in the first chapter that "the resilient resists shocks and stays the same"[38] undersells a bit what some definitions like the State Department's aspiration to "be creative in the midst of change" seem to suggest. Perhaps resilience is the only concept that is needed, or do we need something that goes farther or is resilience equivalent to antifragility?

The commonality that binds all of these examples is that entity or doctrine mentions some form of recovery as an important aspect of becoming resilient. Recovery is a period whereby the state or international organization returns to its previous state that existed before some stressor.

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[35] "About DARWIN." DARWIN. Accessed 2019. https://h2020darwin.eu/about/.
[36] Kimber, Leah R., and Babette Fahlbruch. "Resilience from the United Nations Standpoint: The Challenges of 'Vagueness.'" Essay. In *Exploring Resilience: A Scientific Journey from Practice to Theory*, edited by Siri Wiig, 89–96. Springer, Cham, 2017.
[37] Mizutori, Mami. "Our Work." United Nations Office for Disaster Risk Reduction. Accessed 2016. https://www.undrr.org/about-undrr/our-work.
[38] Taleb, Nassim Nicholas. *Fooled by Randomness: The Hidden Role of Chance in Life and in the Markets*. New York, New York: Thomson/Texere, 2004.

Thus, the labels of fragile and resilient are referring to an end state of what is often a lengthy process of response and recovery period to a stressor.

As instantiated in the model, a fragile state 'breaks' or gets worse when faced with a stressor. A resilient state ultimately returns to the prior status it possessed before experiencing the stressor. It is more agile at adapting to the stress, it has more ability to marshal and effectively apply power to respond to the stress, and it is able to learn how to adapt to the stress to a greater degree. As mentioned previously in the earlier discussion on resiliency, the literature on recovery informed the agent attribute of a recovery period (*p*) the number of periods during which the state recovers from a shock, which is related to another equally important aspect of recovery in the model, magnitude. Recovery magnitude (*m*) is defined as how well an entity may recover in a given period of recovery. For a fragile state the total recovery ($\sum_{p=1}^{p} m$) *is less than its loss from shock*. By contrast, for a resilient state recovery ultimately returns it to the original status so the total recovery ($\sum_{p=1}^{p} m$) *is equal to the performance loss from the shock.* As the alert reader will have already anticipated, for an antifragile state is different from either of these cases: the recovery from a shock ($\sum_{p=1}^{p} m$) *is greater than the performance loss from the shock.*

Quantifying Fragility and Resiliency

Two of the most notable frameworks for assessing and classifying fragile and resilient states are the Organization for Economic Co-Operation and Development's (OECD) Development Co-operation Directorate reports and the Fragile States Index (FSI). The OECD index is an international organization whose goal is to shape policies that foster prosperity, equality, opportunity, and well-being for all. Working together with governments, policy makers, and citizens, OECD works on establishing international norms and finding evidence-based solutions to a range of social economic and environmental changes.[39] In 2005, the Fund for Peace, a United States think tank, and the American magazine, *Foreign Policy*, began to publish an annual report known as the Failed States Index. This report aimed at assessing states' vulnerability to conflict or collapse. Today, that same index has undergone a rebranding of sorts by going by the name the Fragile States Index instead.

While both the FSI and OCED indices are thorough and sound in their data collection and methodology, both have a significant limitation in their application to state antifragility. That is, both indices fail to conceptualize any measure beyond resiliency, potentially leading policy makers and states to believe that achieving the status of resilient is the ultimate goal. Recall from the previous section that, resiliency indicates that a state is only ever capable of recovering to a pre-shock level, and are thus, incapable of improvement beyond that of resiliency. However, given the observance of examples whereby states benefit from disorder, it stands to reason that inclusion of this measure should be added to the very indices that assess a state's vulnerability to collapse or conflict.

In light of this limitation, the model in Chapter 4 expands state categorizations to include a category whereby states may achieve a classification beyond that of resilient called antifragile. As will be discussed below, I argue that states with more capacity to learn, more agility, and more capability to engage in effective power conversion are more likely to be antifragile when faced with shocks: they will get better instead of merely recovering to their pre-shock status.

BEYOND FRAGILITY AND RESILIENCE: THE ANTIFRAGILE

Heavily influenced by his background in economics and the impact of the 2008 market crash, Nassim Taleb introduced readers to the concept of antifragility in his 2012 book,

[39] OECD (2018), *States of Fragility 2018*, OECD Publishing, Paris, 2018. https://doi.org/10.1787/9789264302075-en.

Antifragile: things that gain from disorder. Recall from earlier that a system is deemed fragile when it is significantly disrupted and breaks due to shocks applied to that system. Additionally, a system is deemed resilient when it recovers back to its pre-shock levels. Antifragile describes a system that can not only withstand shocks to it but a system that benefits from these shocks or mishandlings: when it recovers from the shock it is better than before. Moreover, the antifragile welcomes and accepts stress rather than resists it. On the surface, antifragility possesses a commonsense intuition about it, but because society is not primed to think in terms of antifragility, we do not consider it. Likewise, because we have means of measuring and quantifying fragility, it is far easier to figure out if something is fragile rather than antifragile. Taleb explains, the reason for this is because there is no known word for it in the English language.[40] However, as Taleb explains just because one has not observed a phenomenon does not imply the absence of its existence.

To gain a better understanding of antifragility, it is useful to think of a familiar and simple example. Consider exercising the body. During exercise stress is applied to the body over a certain duration of time. These stresses on the body, whether they be aerobic or anaerobic, can lead to a temporary weakness in the muscles. That is, muscles may hurt or not perform at their maximum capacity in the next few hours or days in response to the stress applied to them previously; however, this period of increased weakness and strain occurs for short time span only. The body's longer-term response to exercise often leads to strengthen muscles and improved health, despite this temporary deterioration. As discussed above total recovery from the stress ($\sum_{p=1}^{p} m$) *exceeds the performance loss from the shock.* Regular exercise thus produces increases in strength and endurance. This example demonstrates how shocks to the

[40] Taleb, Nassim Nicholas. *Antifragile: Things That Gain From Disorder*. New York, NY: Random House, 2014.

system in the form of exercise to the body, can cause temporary strain or weakness on the system in the short term but can lead to increased strength or systemic benefits in the long term.

In fact, through further examination and application, antifragility can be seen virtually everywhere, innate to all life on earth. Taleb asserts that evolutionary systems that have developed on their own and that are built the bottom up are evidence of antifragility. Over millions of years these systems have responded to stress with innumerable adaptations. While many species have gone extinct, life itself has diversified and proliferated. Hence within biology we see antifragility at the individual level (i.e., exercise example) and at the inter-species systemic level in evolutionary adaptation to adapt to and thrive in the face of the stresses associated with innumerable environments and biological niches.

While biological systems provide intuitive examples of antifragile systems, antifragility is not limited to just the fields of biology and anthropology. Taleb provides an example from chemical engineering by discussing carbon nanotubes. Carbon nanotubes are an allotrope of carbon with a cylindrical nanostructure that possess remarkably uncommon thermal conductivity, mechanical, and electrical properties that when arranged in a certain manner produces self-strengthening response previously unseen in synthetic materials, "similar to the localized self-strengthening that occurs in biological structures."[41] That is, when arranged in a certain manner, the carbon nanotube exhibits this property of antifragility.

Sources Of Antifragility

Many academic fields have begun to incorporate antifragility into their research agendas. Due to its inextricable relationship with stress, antifragility has been applied to many fields of study that examine stress as part of their area of study. Economics and market volatility,

[41] Taleb, Nassim Nicholas. *Antifragile: Things That Gain From Disorder*. New York, NY: Random House, 2014.

psychology and stress, biological systems and evolution were some of the first to embrace the concept of antifragility, and to begin examining the sources of antifragility.

What leads some entities to be more antifragile? As an introduction to antifragility, Taleb asserts that antifragile systems have several key properties. These properties include sticking to simple rules, decentralization, the development layered systems, building in redundancy and overcompensation, resisting the urge to suppress randomness, and ensuring everyone has skin in the game. (Figure 1). The work that follows argues that these rules generally lead to states that are better at achieving three "propensity factors" that enable antifragility (learning, agility, and power conversion) and are explored further through the analysis of the model results later in the paper.

Figure 1: Antifragile System Design Principles[42]

[42] Sterling, Bruce. "Antifragile System Design Principles." Wired, April 17, 2013. https://www.wired.com/2013/04/antifragile-system-design-principles/.

First, Taleb asserts that simplicity is superior. In fact, he warns us not to walk into the temptation of "responding to complexity with complex rules" for the unintended consequences are perilous.[43] Overly complex or complicated rules muddle the system and abundance seems preferred to scarcity. This design principle is also mentioned by Barth, Meyer, and Spitzner (2012) as the "complexity pitfall" in simulation modeling.[44] As a representation of a real-world entity or system, Barth, Meyer and Spitzner write, "the model structure has to represent reality with sufficient precisions for the simulation to yield applicable results. It is this balancing act between simplifying and exact representation. However, going to much in the direction of exact representation of the target system this bears the risk of drowning in details and losing sight of the big picture. The resulting model structure becomes increasingly complex and comprehensive."[45] The model presented in Chapter 4 was informed by this design principle of start simple and add complexity later.

Similar to simplicity, Taleb repeatedly points to decentralization as the second key characteristic of an antifragile system. Whereas centralized systems are fragile because the rules by which they abide are so broad and theoretical that ultimately, they lack a relevant social context, decentralization allows for a system to learn from randomness. Daniel J. Mitchell's article *Success of Decentralization* explains that "decentralized systems are much more stable and successful since there's far less risk of a mistaken policy being imposed on a one-size-fits-all

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[43] Taleb, Nassim Nicholas. *Antifragile: Things That Gain From Disorder*. New York, NY: Random House, 2014.
[44] Rolf Barth, Matthias Meyer, and Jan Spitzner. "Typical Pitfalls of Simulation Modeling-Lessons Learned from Armed Forces and Business." *Journal of Artificial Societies and Social Simulation*, 5, 15, no. 2 (March 31, 2012): 2019. https://doi.org/10.18564/jasss.1935.
[45] Rolf Barth, Mattias, Meyer, and Jan Spitzner, Typical Pitfalls of Simulation Modeling-Lessons Learned from Armed Forces and Business.

basis."[46] It is through this tenant of antifragility that learning is emphasized, as will be discussed in more detail later.

As an extension of the simplicity, Taleb contends that layered systems must be developed within the broader system. This is because an antifragile system often learns from and adapts through the fragility of its components. By having a layered system, an antifragile system can contain the adverse impacts of failure at smaller, local levels where learning occurs. Failures at the local level insulate the larger system from a more catastrophic systemic failure. To illustrate this principle, recall the example of the human body, but now focus on the response to disease. The human body is built out of many cells. When we have an infection, the immune system is not able to protect all cells. Indeed, the immune system may assist the destruction of infected cells, but the immune response to the infection and death of some cells often allows the body to contain the infection, while the experience trains the immune system to defeat a similar pathogen more rapidly in the future. Therefore, as a result of the infection (stress), some cells died (broke) and the body became more capable of defeating the stressor in the future.

A closely related characteristic to layered systems is that of redundancy and overcompensation. While redundancy and overcompensation are often viewed as inefficient or wasteful when discussing government for example, Taleb offers this contrary perspective when discussing antifragility. He notes that redundancy and overcompensation are a form of insurance that "prove helpful, not just surviving unexpected stress, but to provide the resources required to address windows of opportunity that often arise in times of turmoil."[47] Taleb, again, points to the design of the human body to illustrate the importance of redundancy. Two eyes, two ears

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[46] Mitchell, Daniel J. "The Secret of Swiss Success Is Decentralization." FEE, July 2, 2016. https://fee.org/articles/the-secret-of-swiss-success-is-decentralization/.
[47] Taleb, Nassim Nicholas. *Antifragile: Things That Gain From Disorder*. New York, NY: Random House, 2014.

and two kidneys are just a few of the examples of redundant pathways built into the human body, allowing for the failure of one to prevent catastrophic consequences for the entire system. However, the idea of redundancy and overcompensation are not unique to biological systems alone. Named after Joint Chief of Staff and National Security Advisor General Colin Powell, the Powell Doctrine urged "an overwhelming force" be used to combat military adversaries. By entering Kuwait during the first Gulf War with massively more troops than needed, General Powell and United States President George H.W. Bush were able decisively defeat Saddam Hussein's army, limit the ground-combat phase of the first Gulf War to an astonishing one-hundred hours, and inflict highly asymmetric casualties.[48]

Next, while redundancy helps protect systems or entities against the randomness of the environment, Taleb maintains that one must in fact fight the urge to resist randomness. Instead, randomness should be embraced rather than eliminated. As resistance towards randomness increases, so too does a system's vulnerability to disruption. In fact, Taleb conjectures that one way to "fragilize" a system is to simply put into effect measures that suppress randomness and volatility.

Finally, Taleb states that everyone must have what he refers to as "skin in the game." Simply put, participants must face the consequences of their actions, endure failure, and enjoy success when appropriate.

One of the most thorough early examinations of the characteristics of antifragile systems is in work by John Johnson and Adrian Gheorghe.[49] The authors examine ten "analytical criteria" they argue influence the degree of fragility, resilience and antifragility in systems.

[48] What Was the Powell Doctrine?, The Carnegie Council for Ethics in International Affairs, Retrieved From: https://www.carnegiecouncil.org/education/008/expertclips/005

[49] Johnson, John, and Adrian V Gheorghe. "Antifragility Analysis and Measurement Framework for Systems of Systems." *International Journal of Disaster Risk Science* 4, no. 4 (2013): 159–68. https://doi.org/10.1007/s13753-013-0017-7.

Several criteria seem primarily associated with fragility and exposure to danger. They argue that time and system *entropy* reduce the ability of systems to "use information to transform inputs into desired outputs" increasing vulnerability to large stressors (which they term "X-events").[50] Hence systems that are less agile and less capable of learning are more likely to be fragile. Several other characteristics also are associated with heightened fragility including less redundancy (fewer reserves to deal with challenges means a system is more likely fragile), too tight a coupling between system components (which can cause failures to "reverberate" instead of being contained, and an inappropriate balancing of "constraints versus freedom" (too loose increases exposure and risk), and "requisite variety."

Several other criteria are principally associated with the ability to rebound to the status quo after a stress or X-event, including "absorption" and "redundancy" which both increase the capability to absorb stress without suffering catastrophic failure (which may allow the system to survive in order to take advantage of new opportunities). Systems that possess these properties are better able to convert latent power and capabilities to address stresses.

Finally, they argue that some criteria are associated with the potential emergence of antifragility in the system. For instance, Johnson and Gheorghe assert that "learning from mistakes can be an effective defense against stressors... In this case, stressors can actually cause the system to improve." Furthermore, they write, "applying regular and controlled stress to a system can increase its robustness and potentially lead to antifragility."[51]

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[50] Johnson, John, and Adrian V. Gheorghe. "Antifragility Analysis and Measurement Framework for Systems of Systems."
[51] Johnson, John, and Adrian V Gheorghe. "Antifragility Analysis and Measurement Framework for Systems of Systems." *International Journal of Disaster Risk Science* 4, no. 4 (2013): 159–68. https://doi.org/10.1007/s13753-013-0017-7.

I will develop a synthesis of these arguments more thoroughly below. In brief, my claim is that systems which effectively learn from failures and mistakes while displaying agility and converting power to avoid catastrophic failure are best positioned to exhibit antifragility.

Interdisciplinary Applications of Antifragility Ideas

The following section examines many of the interdisciplinary applications of antifragility ideas. These applications are varied and wide ranging and include issues related to botany, economics, and psychology and demonstrate the potential importance of the antifragility concept across various disciplines.

The Fall 2013 issue of Plant Healer Magazine provided an important lesson in antifragility. The article, *Turkey Tail Mushrooms & The Antifragility of Immunity* suggested that the Turkey Tail mushroom when ingested, stresses our small intestine by docking with receptors located there; however, just as it is simultaneously stressing our small intestines, so too are the Turkey Tail mushroom's B-glucans helping our immune systems adapt. To the body, B-glucans resemble a bacteria cell, and the introduction of this bacterial shock to the small intestine in turn initiates an immune response within the body. As a result of this discovery, the Turkey Tail mushroom is now widely used in contemporary cancer treatment, and other areas of research support are expanding and include, HIV, HSV, Hepatitis C, and chronic fatigue syndrome in Asia today.[52] Again, the importance of the presence of stress as a manner by which antifragility can be achieved is underscored in this unlikely source. Furthermore, it dispels the notion that stress if often considered to be bad. Stress in and of itself is not bad. It depends upon the amount and the context. No stress is unhealthy. Too much stress is unhealthy, but the right amount of stress is healthy. As this example shows, a bacterial shock to the small intestine can

[52] "Coriolus Versicolor." Memorial Sloan Kettering Cancer Center. Accessed 2019. https://www.mskcc.org/cancer-care/integrative-medicine/herbs/coriolus-versicolor.

trigger an immune response which can be used to further position to body to deal with bigger, more consequential stressors, such as cancer.

In the *Economic and Environmental Studies Journal*, Joost Platje examines the relevance of antifragility for sustainable development and organizational sustainability in his article, *Sustainability and Antifragility*. Platje even goes so far as to call for a paradigm shift from resilience of systems and organizations towards antifragility. Platje's argues antifragility as not only a state beyond resiliency but one that is necessary for intergenerational sustainability and long-term survival. As Platje writes, "More is needed than resilience, which rather focuses on the capacity and capability to recover from different shocks. Sustainability strategies should focus on prevention or elimination of unsustainable activities or fragilities, replacing them, when necessary, with less unsustainable activities."[53] In other words, if we are to aim for resilience as being the ultimate goal for survival, then we will always focus on fortifying our capacity and capability to recovery to a state prior to that of the stressor. That is, we have peaked and cannot enhance our stature and position in the hierarchy of states, organizations, or even society. Should we focus to achieving antifragility as the goal, and not resiliency, then activities or structures which render fragilities become the focus and sustainability can be achieved.

In *Antifragility, the Black Swan and Psychology: A Psychological Theory of Adaptability in Evolutionary Science*, Brendan Markey-Towler seeks to give evolutionary and institutional economics "a deeper foundation in psychological theory by constructing a new theory of the mind as a network of structure within which and upon the psychological process operates to identify psychological properties of the antifragile personality."[54] He points out that antifragility

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[53] Platje, Joost. "Sustainability and Antifragility." *Enviornmental & Socio-economic Studies* 15, no. 4 (December 2015): 469–77. https://www.researchgate.net/publication/298457492_Sustainability_and_antifragility.

[54] Markey-Towler, Brendan. "Antifragility, the Black Swan and Psychology: A Psychological Theory of Adaptability in Evolutionary Socioeconomics Systems," February 27, 2018. http://dx.doi.org/10.2139/ssrn.3130038.

is a property of some structure that grows and develops because of radical uncertainty, not in spite of it. In the same fashion as Taleb's Design Principles of Antifragility, Markey-Towler suggests that uncertainty or randomness be embraced and not suppressed. How then "does one plan and act in a world where events might arise which one could not even be hitherto conceived, let alone assessed for likelihood?"[55] Here it is useful to reference the works of George Shackle, a prominent English economist who challenged classical rational choice theory.

Shackle challenged the conventional role of probability in economics, contending that it failed adequately to deal with surprising events. As Markey-Towler writes,

> Shackle's work explains that individuals might first build up a profile of "surprise" based on the impediments they imagined and might prevent certain events from happening. They established that they would be somewhere between "astounded" and "not at all surprised" were certain events to arise. They then acted guided by the "ascendency function" which reflected the attention-grabbing nature of events which would have both significant impacts and a certain level of surprise which commanded attention prior to the event (focal points). Shackle (especially in *Decision, Order and Time*) took pains to distinguish this inherently fluid and subjective process from the strict constraints and objectivity posited by expected utility theory. Earl and Littleboy (2014) suggest that in doing so, he discovered an early variant of Tversky and Kahneman's prospect theory. (Markey-Towler, 2018)

To put it differently, George Shackle challenged the conventional role of probability in economics as a challenge to classical rational choice theory, citing that it failed to adequately deal with surprising events. As Markey-Tower points out, it is suggested that he discovered an

[55] Markey-Towler, Brendan. "Antifragility, the Black Swan and Psychology: A Psychological Theory of Adaptability in Evolutionary Socioeconomics Systems."

early variant of Tversky and Kahneman's prospect theory, a behavioral model that shows how people decide between alternatives that involve risk and uncertainty. Whereas expected utility theory models the decision that perfectly rational agents would make, prospect theory aims to describe the actual behavior of people. In doing so, he highlights the importance of decision making in conditions of uncertainty. Again, randomness, uncertainty, and risk are to be understood and embraced rather than suppressed.

Markey-Towler's question of what constitutes the antifragile personality is of significant importance for evolutionary and institutional economics, concluding his piece by mentioning institutions. Although he most assuredly is referencing economic institutions, the notion of institutions, writ large, is certainly a valid substitute when thinking about antifragility. Markey-Towler concludes,

> We know that institutions which order our socioeconomic systems are in constant, evolutionary flux. They are constantly being originated, diffused by their selection in the competition and evolution of ideas and in the public sphere and retained as rules for guiding through and behavior across society. They are, ultimately, born of creativity (of a sort) and the system which selects or deselects them is, as Hayek (1989) showed, unfathomably complex due to the sheer number of people who inhabit it all with intricate, individuated and constantly evolving schema for interpreting and acting in the world. Hence, we can establish certain tendencies in these systems but here is a case to be made that a degree of nihilism is inevitable due to the radically uncertain nature of our socioeconomic systems. All schemas for interpreting our socioeconomic system and how best to act in them will inevitably fail to align with reality, which is really the whole point of George Shackle and Nassim Taleb's work. (Markey-Towler, 2018)

Again, the importance of dynamism in the case of institutions and the socioeconomic systems that produce them is ever changing, thus any sort of schema for how best to interpret and act in them will fail if we fail to recognize this dynamism and uncertainty. Taleb takes this a step further by pointing out that in order to not just survive, but to thrive and endure, uncertainty must be embraced. Referring back to Pjlate, this must also be the case to achieve long term sustainability.

Though there are many adaptations of antifragility to various fields, there are commonalities across these adaptations. First is the observation that antifragile systems are dynamic. That is to say, they are characterized by change, activity, and progress as a result of interactions. Second, at the level of human institutions, antifragile systems can be intentionally constructed exploiting mechanisms that give rise to antifragility.[56] That is, once the design principles of antifragility are understood, they can then be utilized by states or non-governmental organizations, for example, to construct institutions or states that are antifragile, or beyond resilience. How to construct a fragile or antifragile state is discussed further in the literature review when examining, *The Calm Before the Storm: Why Volatility Signals Stability, and Vice Versa* later in this chapter. This understanding only emphasizes the importance of thinking about antifragility, studying antifragility, and including it in our language and understanding of a multitude of disciplines, especially that of states and International Relations.

Antifragility in International Relations

To understand the importance of applying and theorizing about antifragility within the field of International Relations one must begin where International Relations has the greatest

[56] Albino, Dominic K, Katriel Friedman, Yaneer Bar-Yam, and William Glenney. "Military Strategy in a Complex World," February 18, 2016. https://doi.org/arXiv:1602.05670.

need. That is, we must understand where International Relations falls short in explaining certain phenomena within the international system.

This shortfall resides in both the theoretical and methodological approaches to understanding the actions or inactions of nation-states. Theoretically speaking, the weakness of Realism in International Relations presents an opportunity for the application of antifragility to supplement, not supplant, the explanatory power of Realism. Methodologically speaking, probabilistic risk assessment, game theory, and Thomas Schelling's strategic realism are analytic tools used for strategic thought, derived from a Realist viewpoint. Together with their theoretical relative, Realism, these methods have their deficiencies that have failed to accurately understand risk and predict the subsequent events born out of that failure.

Antifragility and States

As noted in the beginning of this chapter the literature directly focusing on antifragility and International Relations is sparse, and political scientists and economists have only begun to peripherally apply the concept of antifragility within the field of International Relations. Though literature directly applying antifragility to concepts within International Relations is relatively rare, it does exist, albeit with each piece of literature discussed below applying only a portion of antifragility to pertinent puzzles.

Halil Rahman Basaran, "explores the concepts of fragility, robustness, antifragility, reification, world risk society, modernity, information international lawmaking, and their relationship to international law in the field of the responsibility to protect (R2P)"[57] in their journal article, *Responsibility to Protect: An Anti-Fragile Perspective,* [58] Additionally,

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[57] Basara Basaran, Halil Rahman. "Responsibility to Protect: An Anti-Fragile Perspective." *Mississippi Law Review*, 5, 32, no. 3 (2014). https://doi.org/ https://dc.law.mc.edu/lawreview/vol32/iss3/5.
[58] Basaran, H. R. (2013). Responsibility to Protect: An Anti-Fragile Perspective. *Mississippi College Law Review*.

Emmanuel Ifeanyi Ani's *A United States of Africa: Insights from Antifragility* argues for the re-examination of the possibility of political integration of the African continent by exploring how the concept of antifragility shapes this topic. Ani specifically focuses on the implications of antifragility to the relationship between cultural heterogeneity and multi-cultural unity, arguing like Markey-Tower and Taleb, that "too much comfort is a fragilizing process, and to the extent that homogeneity in any form is comforting, it is also fragilizing. Cultural heterogeneity in this context is a stressor since it involves the challenge of being able to relate with others at all levels of human interaction, ranging from the interpersonal, through the inter-family, inter-tribal, international to the inter-racial. There are advantages to be derived from becoming increasingly competent in the ability to relate multiculturally, and thus becoming multiculturally antifragile."[59]

But where does antifragility reside in the immense field of International Relations, and are the current methodological tools to better measure and gain insight into antifragility sufficient for the task? The first half of the previous two questions places emphasis on the end state. That is, assigning a "home" for antifragility within an array of concepts and subdisciplines. Notably, it is a *Foreign Affairs* article that provides us with a beginning from which scholars and researchers may follow. Rather than focus on areas of concentration within International Relations such as international law or international political economy, Nassim Taleb and Gregory Treverton apply antifragility to the most central concept and unit of analysis within our field, states, in their article, *The Calm Before the Storm: Why Volatility Signals Stability, and Vice Versa*.[60]

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[59] Ani, Emmanuel Ifeanyi. "A United States of Africa: Insights from Antifragility." *Philosophia Africana* 16, no. 2 (2014): 95–117. https://doi.org/10.5840/philafricana20141627.
[60] Endnote explaining that IR is examined across concentrations such as international political economy and security studies for example. Additionally, each of these concentrations exists across a variety of theories in International Relations such as Realism and Constructivism. Finally, there are levels of analysis within International Relations-the individual level, the group level, the state level, and/or the system level.

The Calm Before the Storm: Why Volatility Signals Stability, and Vice Versa is an adapted essay from a US government funded RAND risk-methodology report that lays out five principal indicators or sources of state fragility. The *Foreign Affairs* piece and its subsequent principal sources of state fragility are predicated on subjective, behavioral observations of states in the international system. Notwithstanding, Taleb and Treverton provide the most comprehensive application of antifragility to states to date through in their work. These five sources of state fragility include a centralized governing system, an undiversified economy, an excessive debt to leverage ratio, a lack of political variability, and little to no history of surviving past shocks.

The authors identify the significance of these indicators to the international political world order when they write, "applying these criteria, the world map looks a lot different. Disorderly regimes come out as safer bets than commonly thought-and seemingly placid states turn out to be ticking time bombs."[61] When compared with the indicators found in the FSI Index or OECD Index, Taleb and Treverton's inclusion of variables such as the history of surviving past shocks provides a different view of the world than the ones presented in the aforementioned indices. In these indices, the presence of shocks (e.g., popular pressures) is taken as an unambiguous indicator of fragility. According to Taleb and Treverton, having a history of surviving past shocks is important to antifragility. States needs to experience stress over time in order to learn from and ultimately gain from those experiences in order to better deal with future stresses. Under the FSI Index and OECD Index, states that experience a lot of volatility or a high number of stressors are considered unstable or fragile. Even so, when examined through a lens

[61] Taleb, Nassim Nicholas, and Gregory F. Treverton. "The Calm Before the Storm: Why Volatility Signals Stability, and Vice Versa." Foreign Affairs, 2015. https://www.foreignaffairs.com/articles/africa/calm-storm.

of antifragility and through the inclusion of a lengthy history of time, this same variable signals strength. In other words, perhaps not all is as it seems.

One primary limitation of the work of Taleb and Traverton is that the authors do not provide their readers with a theoretical home for the topic of antifragility. Still, by describing a preliminary set of indicators of a state's fragility they have provided researchers with a seed of inspiration for the reinvigoration of the topic of state fragility, through their discussion and application of fragility's complement, antifragility. This dissertation addresses this limitation by theoretically anchoring the concept of antifragility in the school of Realism as is discussed in greater depth in the next section. Likewise, realism plays a prominent role in the model of antifragility as the agent's main goal is survival.

ANTIFRAGILITY AND INTERNATIONAL RELATIONS THEORY

Core tenants of International Relations reside predominantly in its theories about state behavior. That is, one of the main objectives of our theories is to explain change in the behavior of states and other international actors. The aptitude with which states respond to changes in the international environment holds great consequences that can have a ripple effect throughout the international system, itself leading to shifts in the curious course of history. From domestic politics to the world economy, foreign policy to the causes of war and conditions of peace, change and state behavior in the international system are important areas of inquiry. Why do states behave in the ways they do in response to change? What state factors cause states to act in some instances and abstain from action in others? Most importantly, under what conditions do these actions and inactions arise? Seeking the answers to these questions is no trivial undertaking. Moreover, hierarchical relationships within the international system that may be characterized as cooperative or conflictual and that are conditioned by certain factors that impact the nature of these relationships, only enhance the layers of complexity to their field's simplest underlying question: why do states behave the way they do in response to change?

International Relations theorists have argued for years about how best to explain international change. Through a neoclassical lens, Robert Gilpin sought to explain why change occurred in the first place.[62] Neorealist, Kenneth Waltz, explained why change does not occur for a long period of time in his book, *Theory of International Politics*. Daniel Deudney and John Ikenberry sought to explain how particular changes came about.[63] Robert Jervis tried to use theories of learning to help understand international relations in *Perception and Misperception in International Politics*. Breslauer and Tetlock edited a volume on the role of learning in international relations.[64] The most compelling thing take away from the work of Breslauer and Tetlock is their focus on learning, particularly as it relates to how foreign policy is conducted. According to Alexander George, their work on learning made "a unique contribution to the development of theoretical and methodological tools for the study of foreign policy change."[65] Thus, Breslauer and Tetlock's foundational work underscores the importance of learning to state behavior change. Few, however, have focused on the actual process and mechanisms of state behavior in response to change in an effort to better understand and explain the process state behavior. The model in this dissertation identifies learning as one of the three essential propensity variables of state fragility/antifragility. And as discussed above, (see the analysis of Johnson and Gheorghe's criteria) the ability to learn from stresses is likely the most crucial capability for the development and maintenance of antifragility in any system including states.

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[62] Gilpin, Robert. *War & Change in World Politics*. Cambridge, UK: Cambridge University Press, 1981.
[63] Deudney, Daniel, and G. John Ikenberry. "The Nature and Sources of Liberal International Order." *Review of International Studies* 25, no. 2 (April 1999): 179–96. https://www.jstor.org/stable/20097589.
[64] Farkas, Andrew. *State Learning and International Change*. Ann Arbor, MI: The University of Michigan Press, 1998.
[65] Breslauer, George, and Philip Tetlock, eds. *Learning in U.S. and Soviet Foreign Policy*. New York, NY: Routledge, 1991.

To add a level of complexity to this quest, scholars of International Relations find themselves divided into theoretical schools of thought whereby fundamental tenants governing these schools are often in direct contrast with one another. As nationally renowned Old Dominion University International Relations scholar Steve Yetiv once said, "in international relations, where you stand depends on where you sit."[66] Furthermore, each school is incomplete with its own set of critics and sub-schools that seek to provide slightly varying alternative views. Understanding these schools and sub-schools is imperative if the International Relations scholar is to push the bounds of his or her field and ultimately attempt to demystify the mystery of state behavior.

Realism and Power

The core assumption of Realism is that world politics exists and operates within an anarchic international system. Anarchy is defined as, "a system with no higher, overarching authority, no world government."[67] In addition, the principal actor in this anarchic system is the state; therefore, the relations of states are of greatest importance to International Relations scholars such as Hans Morgenthau. Other actors outside of the bounds of the state system such as non-governmental actors, international institutions, and individuals are deemed less important. According to Realists, a hierarchy of power exists among states. The struggle between the great powers for security and domination is of the greatest interest to subscribers of this school of thought. The following four basic tenants can therefore summarize realism:

- First, humans are considered egoistic and self-interested, thus producing a pessimistic view of human nature.

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[66] Miles Jr, R. E. "The Origin and Meaning of Miles' Law." *Public Adm Rev.* 38, no. 5 (September 1978): 399–403.
[67] Jackson, Robert, and Georg Sørensen. *Introduction to International Relations: Theories and Approaches (6th Edn)*. Oxford, UK: Oxford University Press, 2018.

- Second, a belief that international relations are inherently conflictual and that international conflicts are ultimately resolved through war subsists.
- Third, there exists a high regard for the values of national security and state survival.
- Finally, a basic skepticism exists that there can be progress in international politics.

Neorealism, a derivative of realism, focuses on the structural constraints that determine behavior in international relations. Within this school of thought, states may possess similar needs, but do not possess the same capabilities for meeting those needs. The positional placement of states in terms of abilities, thus determines the distribution of capabilities. This structural distribution of capabilities in turn limits cooperation among states through fears of relative gains made by other states and the possibility of dependence on other states. The desire and relative abilities of each state to maximize relative power constraints each other and result in a 'balance of power' which shapes international relations. But what is power?

The concept of power in International Relations can be viewed in a variety of ways. Power as a goal of states or leaders. Power as a measure of influence or control over outcomes, events, actors, and issue. Power as a victory in the attainment of security; power as control over resources and capabilities, and power as a status.

The leading proponent and theorist of power in International Relations is Joseph Nye, who simply defines power as the "ability to get other people to do things they otherwise would not do."[68] While this definition may seem simple on the surface, the concept of power is more dynamic and changes with relation to its surrounding environment. In his book, *The Future of Power*, Joseph Nye writes, "in the era of Kennedy and Khrushchev, power was expressed in terms of nuclear missiles, industrial capacity, numbers of men under arms, and tanks lined up

[68] Nye Jr., Joseph S. "Soft Power." *Foreign Policy*, no. 80 (1990): 153–71.

ready to cross the plains of Eastern Europe. By 2010, none of these factors confer power in the same way: industrial capacity seems an almost Victorian virtue, and cyber threats are wielded by non-state actors. Politics changed, and the nature of power—defined as the ability to affect others to obtain the outcomes you want—had changed dramatically. Power is not static; its story is of shifts and innovations, technologies and relationships."[69] That is to say, power, much like antifragility is dynamic.

Refining this notion, Nye discusses three types of power- soft power, hard power, and smart power. Soft power is defined as the ability to shape preferences of others through appeal and attraction rather than by coercion.[70] Instruments of soft power include debates on cultural values, dialogues on ideology, the attempt to influence through good examples and the appeal to commonly accepted human values. Means of exercising soft power include diplomacy, dissemination of information, analysis, propaganda, and cultural programming to achieve political ends. Hard power is defined as the use of military and economic means to influence the behavior or interest of other political entities. This form of political power is aggressive in nature. Hard power encompasses a wide range of coercive police, such as coercive diplomacy, economic sanctions, military action and/or the forming of military alliances for deterrence and mutual defense. Defined as the capacity of an actor to combine elements of hard power and soft power in ways that are mutually reinforcing such that the actor's purposes are advanced effectively and efficiently, smart power has come to be considered a national security imperative in today's modern diplomatic environment.

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[69] Nye Jr., Joseph S. *The Future of Power*. New York, NY: Public Affairs, 2011.
[70] Nye Jr., Joseph S. *Bound to Lead: The Changing Nature of American Power*. New York, NY: Basic Books, 1991.

Earnest J. Wilson III further delves into the concept of smart power in his article *Hard Power, Soft Power, Smart Power*, when he writes, “a conceptually robust and policy-relevant framework for smart power should be built on a few additional core considerations:

- The *target* over which one seeks to exercise power-its internal nature and its broader global context. Power cannot be smart if those who wield it are ignorant of these attributes to the target populations and regions.
- *Self-knowledge* and understanding of one’ own goals and capacities. Smart power requires the wielder to know what his or her country or community seeks, as well as its will and capacity to achieve its goals.
- The broader *regional and global context* within which each action will be conducted.
- The *tools* to be employed, as well as how and when to deploy them individually and in combination. (Wilson, 2008)[71]

In his latest book, *The Future of Power*, Joseph Nye provides a synthesis of his ideas about the decline of the United States and the rise of China through a refined lens of power. Nye argues while traditional measures of hard power, economic and military capabilities, are still relevant, their use in today’s modern society places a greater premium on information, communication, and legitimate authority. Ultimately, power must be both disaggregated into various dimensions and viewed within specific geographic and historical contexts. In short, power has changed dramatically from a static entity to a dynamic entity sensitive to innovations, technologies, and relationships.

[71] Wilson, Earnest J. “Hard Power, Soft Power, Smart Power.” *The ANNALS of the American Academy of Political and Social Science* 616, no. 1 (March 1, 2008): 110–24. https://doi.org/10.1177/0002716207312618.

Markedly, Nye's latest variant on power, *power conversion,* is defined as "getting from resources to behavioral outcomes."[72] He notes that having the resources of power does not guarantee the outcome you want. Explicitly, Nye asserts that,

> Smart power goes to the heart of the problem of power conversion. As we saw earlier, some countries and actors may be endowed with greater power resources than others, yet not be very effective in converting the full range of their power resources into strategies that produce the outcomes they seek. Some argue that with an inefficient eighteenth-century government structure, the United States is weak in power conversion. Others respond that much of American strength is generated outside of government by the nation's open economy and civil society. And it may be that power conversion is easier when a country has a surplus of assets and can afford to absorb the costs of mistakes. But the first steps to smart power and effective power-conversion strategies are understanding the full range of power resources and recognizing the problems of combining them effectively in various contexts. (Nye, 2011)[73]

To further Nye's observations, I would submit that in addition to not guaranteeing the outcome you want, having power resources also does not guarantee the outcome you would expect. One such example of this comes from the Iraq War (2002-2011), discussed in greater detail in Chapter 6. The United States military by count of power resources clearly dominated the Iraqi insurgency; however, the mass casualties of US troops and the deterioration of the situation in Iraq from 2003 through 2006 demonstrate it is not about how many resources you possess relative to another, but how you are able to leverage what you have in order to achieve behavioral outcomes or end states.

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[72] Nye Jr., Joseph S. *The Future of Power*. New York, NY: Public Affairs, 2011.
[73] Nye Jr., Joseph S. *The Future of Power*.

Another example of power conversion discussed in greater detail in Chapter 6 is the rise of the Islamic State of Iraq and Syria (ISIS) as a by-product of Al-Qaeda in Iraq (AQI). With the collapse of the Ottoman Empires in 1918, so too collapsed the last Sunni Islamic caliphate of the late medieval and the early modern era. In this sense, the Ottoman Empire served as a means of power generation and conversion of a disparate group tribes, people, ethnicities, and unique histories, all of which were subsumed under the notion of the "caliphate", a means of bringing order through religious dogma in order to convert power to the state. The Ottoman Empire adopted a skilled and tactful taxation system, in which resources (taxes) were levied against a variety of peoples, to include Christians, Jews, Assyrians, etc. Furthermore, with the fall of the Ottoman Empire and subsequent re-alignment of the region under European designs, states were forced to rely on greater authoritarian and totalitarian means to extract resources and compel loyalty. Under the Ottoman Empire, religion in the form of the Caliphate did this. In its absence, struggling regimes relied on compliance at the barrel of a gun.

Rule, rarely challenged from within, and subverted through financial miscalculations, surely relied on religion as a means of compliance, but groups like ISIS pale in comparison. Groups like ISIS are able to compel, while also attempting to offer a caliphate-like jurisprudence and governing system, yet simply do not share the same acquiescence of groups, especially non-Sunnis, that the Ottoman Empire did.

As such, power conversion is identified the second of the three essential propensity variables of state fragility/antifragility. These examples of the importance of power conversion rather than the traditional, static measurement of resources as a measure of power, naturally leads to the question of which states are better at converting power, and is power conversion an important aspect of state antifragility?

The Limitations Of Taleb and Treverton

While the work of Taleb and Treverton is a cornerstone for the model and analysis in this dissertation, it is not exempt from limitations. Taleb and Treverton's five characteristics of fragility were never formally defined in their Foreign Affairs article, leaving the reader to interpret each as they see fit. From this disparate list of variables, it became obvious that greater cohesion among them was necessary in order to better understand state antifragility. Moreover, it is important to avoid demarcating Taleb and Treverton's five characteristics as the sole characteristics of state fragility/antifragility. Rather, there are variables that can arguably give rise to fragility/antifragility. I abstract from Taleb and Trevertons' work (along with that of many other authors discussed above) a set of more basic characteristics driving the extent to which states are fragile, robust, or antifragile: three propensity variables. Table 2 below provides a visual mapping of Taleb and Treverton's five fragility variables as they inform the three, newly created propensity variables.

Table 2: Propensity Variables Informed by Taleb and Treverton (2015)

Variables as Defined by Taleb and Treverton (2015)	Directionality of Taleb and Treverton (2015) Variables	Propensity Variables	Directionality of Variables
1. Concentrated Decision Making 2. Political Variability	1.The more concentrated a state's decision making, the more fragile it is. 2. The less political variability a state has, the more fragile it is.	Agility	1. The greater a state's agility, the more antifragile it is.
1. Economic Diversity 2. Debt to Leverage Ratio	1. The less a state's economic diversity, the more fragile it is. 2. The greater a state's debt to leverage ratio, the more fragile it is.	Power Conversion	1. The greater a state's power conversion, the more antifragile the state is.

Table 2: Continued

Variables as Defined by Taleb and Treverton (2015)	**Directionality of Taleb and Treverton (2015) Variables**	**Propensity Variables**	**Directionality of Variables**
1. History of Surviving Past Shocks	The less history a state has of surviving a past shock, the more fragile it is.	Learning	The greater a state's learning, the more antifragile the state is

According to Taleb and Treverton, the more concentrated the decision making within the state, the more fragile the state is. Subsequently, the less concentrated the decision making, the more antifragile the state is. Political variability follows the same pattern, but collectively they impact a state's agility which is discussed in the following section. Economic diversity refers to how varied a state's economy is based on a board range of economic activities in a region or country. Debt to leverage ratio assesses how much capital comes in the form of debt. The higher the debt to leverage ratio the more fragile a state is. Similarly, the less economically diverse a state is the more fragile it is. States with these characteristics are less likely to be able to effectively exhibit resilience in the face of shocks, and they are less likely to be able to effectively marshal and convert power to meet challenges. Finally, a history of surviving past shocks is simply a count of how many shocks the state has not only previously experienced but survived, as well. As noted above in the discussion of Johnson and Gheorghe's work, learning from shocks is likely the single most important way a system can exhibit and maintain antifragility. How each of these resulted in the creation of three propensity variables is discussed in greater detail in the remainder of this chapter. It is important to note that the term propensity variable was a deliberate choice as it indicates that these variables have a tendency to produce antifragility, but may not always do so, resulting in outliers. For example, China represents a nation with a highly centralized decision-making apparatus and very low political variability; however, as discussed in the case study in Chapter 7, other variables have overshadowed these to make it arguably antifragile.

The creation of these three propensity variables of antifragility begs the question of what we mean by those variables and why each of the Taleb and Treverton variables falls under these new categories.

AGILITY

State agility is defined as the speed and magnitude with which states sense, respond, adjust, and adapt their strategies, as a function of changing circumstances. [74] Overall, the process by which a state becomes agile is one in which states make small changes quickly, adapt to those changes, and learn from those changes. By adjusting their understanding of the problem and repeating it many times, states are better able to sense and handle future iterations of similar problems.[75]

At the core of state agility, is the state's ability to think, understand, and maneuver quickly with ease. That is, learning is an integral part of the development of a state's agility. Both the degree to which a state has concentrated decision making and political variability is essential to a state's agility. Making small changes quickly and adapting to those changes is contingent upon how much of a state's decision-making centers wholly on area. According to Taleb and Treverton, the more centrally concentrated the decision-making process, the more fragile a state is. Contrariwise, the less concentrated the decision-making process, the more antifragile a state is. Complementing the idea of concentrated decision making is the notion of political variability, as it is a necessity in order to have a diffused decision-making apparatus.

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[74] Pragne, Christiane, and Loizos Hercaleous. "Agility.X-How Organizations Thrive in Unpredictable Times," June 2018.
[75] This definition is partially adopted from the work of Morton, Stacey and Mohn.

According to Taleb and Treverton, the greater the political variability, the more antifragile a state is. Conversely, the less political variability, the more fragile a state is. Upon further examination, these two variables are aligned with the antifragile system design principles referenced earlier in the chapter, particularly that of decentralization, development of layered systems and built-in redundancy and overcompensation.

Agility in Sensing

The first part of the agility definitions focuses on what happens prior to a state's experience of a shock or stressor, or sensing. State agility in sensing is primarily a function of the domestic institutions that are tasked with that problem area. For example, in the United States of America, domestic institutions and departments are designed solely for studying, analyzing, and acting on issues related to intelligence, the environment, and education. Each of these organizations is tasked with monitoring and evaluating changes in each of their respective spheres, anticipating any threats that may disrupt the progress or existence of each.

Upon further examination, it is revealed that to be effective at sensing there must be redundancy, diversity, and modularity built into the system such that when one system fails to sense another may do so.[76] Since the goal of antifragile systems is to thrive in randomness, the systems must contain inefficiencies through layered redundancies. Hole's *Antifragility to Malware Spreading* chapter marks an important milestone in agent-based modeling and antifragility as it is the first model to demonstrate the emergence of antifragility. Hole's work focuses on how to prevent infectious malware from spreading over vast networks of computing devices by devising a technique that stops frequent multi-malware outbreaks with an unknown and time-varying speed mechanism. Hole's chapter specifically focuses on the application for

[76] Sterling, Bruce. "Antifragile System Design Principles." Wired, April 17, 2013. https://www.wired.com/2013/04/antifragile-system-design-principles/.

the "fail-fast principle" to the malware-halting technique. The fail-fast principle is exactly as the name implies. In computer software development, fail fast makes bugs and failures appear sooner. According to Dat Hoang's *The Fail-Fast Principle in Software Development*, when fail fast is implemented, bugs are earlier to detect, easier to reproduce, and faster to fix. Additionally, it is easier to stabilize software, fewer bugs and defects will go into production, thus leading to higher quality and more production-ready software. Finally, the cost of failures and bugs are reduced.[77]

Hole best explains how antifragility emerges in this technique works when he writes, "a system under repeated attacks from malware is antifragile if it first learns to reduce the fraction of infected devices and then manages to keep the fraction small when the malware's spreading mechanism changes."[78] Most notably in this statement is that the goal is not to force the fraction of infected devices to zero, but rather to keep it low over time. As Taleb would say, "systems that are optimized or lack redundancies tend to blow up."[79]

Applied to the field of International Relations, the same principle of redundancy can be utilized by states through its domestic organizations and institutions. The United States of America, for example, has seventeen separate government intelligence agencies within the broader intelligence community. Each works separately and together at times to conduct intelligence activities to support foreign policy and national security of the United States of America. They are structured such that each agency belongs to a different parent agency and department within the United States government, and in some instances, there is overlap.

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[77] Hoang, Dat. "The Fail-Fast Principle in Software Development." DZone, January 2005. https://dzone.com/articles/fail-fast-principle-in-software-development.
[78] Hole, Kjell Jørgen. "Anti-Fragility to Malware Spreading." Essay. In *Anti-Fragile ICT Systems* 1, 1:99–110. Springer, Cham, 2016.
[79] Kemp, W., Boutellis, A., Williams, P. D., Andersen, L. R., Luengo-Cabrera, J., Jawaid, A., & Möller-Loswick, A. (2014, September 22). Risk and Robustness: A Conversation with Nassim Nicholas Taleb. Retrieved From: https://theglobalobservatory.org/2014/09/risk-and-robustness-nassim-nicholas-taleb/'.

Table 3 below provides the organizational structure of the sixteen intelligence community agencies, headed by the Director of National Intelligence (DNI).

Table 3: Organizational Structure of United States Intelligence Agencies[80]

Agency	Parent Agency	Federal Department	Date Established
Office of Naval Intelligence	United States Navy	Defense	1882
Coast Guard Intelligence	United States Coast Guard	Homeland Security	1915
Bureau of Intelligence and Research	United States Department of State	State	1945
Central Intelligence Agency	None	Independent Agency	1947
Twenty-Fifth Air Force	United States Air Force	Defense	1948
National Security Agency/Central Security Service	None	Defense	1952
Defense Intelligence Agency	None	Defense	1961
National Reconnaissance Office	None	Defense	1961
Intelligence and Security Command	United States Army	Defense	1977
Office of Intelligence and Counterintelligence	None	Energy	1977
Marine Corps Intelligence Activity	United States Marine Corps	Defense	1978
National Geospatial-Intelligence Agency	None	Defense	1996
Office of Terrorism and Financial Intelligence	None	Treasury	2004
Intelligence Branch	Federal Bureau of Investigation	Justice	2005
Office of National Security Intelligence	Drug Enforcement Administration	Justice	2006
Office of Intelligence and Analysis	None	Homeland Security	2007

[80] "Members of the IC." Office of the Director of National Intelligence. Accessed 2020. https://www.dni.gov/index.php/what-we-do/members-of-the-ic.

In this example, both redundancy and modularity are represented. Modularity is defined by a system of links. When the functionality of module A at some system level depends on the functionality of another module B, there is a direct link from A to B in the system graph to represent this dependency. Different dependencies have varying strengths. The strength of a dependency can be measured by determining the damage a misbehaving module causes in the dependent module. The result is either a strong or weak link.

In the United States intelligence agency example above, the Marine Corps Intelligence Activity, Twenty-Fifth Air Force, Office of Naval Intelligence, and Intelligence and Security Command all belong to differing branches of the United States military; however, they are all linked in that they are a part of the Department of Defense Intelligence apparatus. There are linkages built-in to the bureaucratic management of the overall intelligence community, but the design is such in that each entity has a specific specialization that contributes to the whole. Additionally, the diversification of the overall intelligence enterprise allows for an inherent redundancy and insulation from acute perturbations (loss of sources, collections platforms, compromise of technologies, etc.). Overall, agility in sensing in one component of agility, overall. Agility in responding is the second.

Agility in Responding

The second component of the agility definition relates to the action part. That is, responding to the stressor or shock. The challenge for states with such an advanced and developed enterprise lies in the ability to harness and control such a vast enterprise in an efficient manner. Returning to our literature on computers and software development as well as business, it is useful to examine the application of the Fail Fast Principle.

The name Fail Fast Principle gives us an indication of the definition. As Jim Shore and Martin Fowler write, "…if failing immediately and visibly sounds like it would make your software more fragile, but it actually makes it more robust. Busts are easier to find and fix, so fewer go into production."[81] In other words in your response, fail immediately, but in such a manner that the failures follow the following four components. Fowler outlines the four tenants of the Fail Fast Principle.

1. *Fail Early:* Here the belief is that if it is possible to learn from failure then the sooner the failure occurs, the sooner the learning begins. By failing early, you can create something useful and deliver it faster. This will allow you to get real and fast feedback about what works and what does not, which you can then adjust before moving forward.
2. *Fail Fast:* Fail quickly as quickly as possible. In other words, do not let the failure drag out over time.
3. *Fail Often:* When the failing and learning loop has been established, we can see that the more things we try, the more failures we can have and therefore the more changes we must both learn and steer our project in the right direction. In addition, this will remove the need to waste time by working on incorrect avenues.
4. *Fail Better:* When failing better do so with the early and frequent failures in order to maximize the learning opportunities. (Fowler, 2015) [82]

It is important to point out that these four components are not meant to prevent errors. Rather this guidance provides us with a way of reducing the cost of those mistakes. The

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[81] "Fail Fast, Fail Often Explained." The ARRK Group, n.d. https://www.arrkgroup.com/thought-leadership/fail-fast-fail-often-explained/.
[82] "Fail Fast, Fail Often Explained." The ARRK Group, n.d. https://www.arrkgroup.com/thought-leadership/fail-fast-fail-often-explained/.

application of this principle may seem easier to fathom in the software development realm rather than with states as it pertains to navigating war, famines, and economic collapse; however, it should be noted that the emphasis of the Fail Fast Principle should be in the preparation for these events, so that when these events occur the learning necessary to successfully navigate these crises has occurred. According to Giles in How to Fail Faster-And Why You Should, those engaged in risk analysis and probability are trying to,

> Predict, control, and eliminate variances. This is a losing game. Reducing variance inevitably meets the law of diminishing marginal returns: the cost of reducing variance evidentially exceeds the benefit. In addition, the goal of controlling and minimizing variance can be deceptive, because we don't know what to measure in a complex environment that changes so rapidly, and we can't control what we can't measure. The minute we figure it out, what we need to measure has changed. For all these reasons, iteration instead of perfection is the more effective way to go…Speed of execution is a lot more important than perfect execution. (Giles, 2018)[83]

Responding also includes having the right controls to manage and measure change so you can seize new opportunities, adapt to new conditions without disruptions, and have lateral freedom rather than be constrained by limitations.

It is important to note, that within the dissertation model does not capture agility to the level of detail that agility in sensing and agility in responding are differentiated or even recognized. Rather, these two concepts were "black boxed" in the agent attribute called agility, which is represented by the recovery period variable. The decision to black box the sensing aspects of this attribute is one of the many design tradeoffs made in this dissertation and was

[83] Giles, Sunnie. "How To Fail Faster-And Why You Should." Forbes, April 30, 2018. https://www.forbes.com/sites/sunniegiles/2018/04/30/how-to-fail-faster-and-why-you-should/?sh=4e5ed03bc177.

made in order to have a higher degree of explainability at the expense of accuracy. Ultimately, the black boxing of this attribute does not diminish the importance of this distinction for future iterations of this topic. Instead, it is important to bring up the connection agility has with recovery period, another characteristic of the agent found in the model. Recovery period is an important source of fragility as the length it takes a state to recovery from one shock directly impacts its ability to sense and respond to future shocks. For example, a state might be tied up in a financial crisis that impacts its ability to pivot and address a shock that demands financial backing to mobilize resources (i.e., fund a war overseas).

POWER CONVERSION

Joseph Nye, like Nassim Taleb, shares the concern of the changing nature of how we view a hierarchy of states and power. Nye writes, "at an even more basic level, what will it mean to wield power in the cyber world of the twenty-first century? What resources will produce power? In the sixteenth century, control of colonies and gold bullion gave Spain the edge; seventeenth century Netherlands profited from trade and finance; eighteenth century France gained from its larger population and armies, while nineteenth century British power rested on its primacy in the industrial revolution and its navy. Conventional wisdom has always held that the state with the largest military prevails, but in an information age it may be that the state (or non-state) with the best story wins"[84] Nye's previous statement yields some interesting insights into power and states that some might gloss over. Nye writes,

> While mentioning each of the key resources from the past five hundred years, Nye begins by discussing how each was leveraged in a way that allowed states to assert power in the international sphere. Pivoting from these examples, Nye then questions one of the

[84] Nye Jr., Joseph S. *The Future of Power*. New York, NY: Public Affairs, 2011.

> traditional measures of state power, military strength. However, in an interesting twist, Nye recognizes the importance of information in the twenty-first century and the means by which power travels. It is the ability to leverage the informational means that has led groups like Al-Qaeda and ISIS to spread their story across the globe, evolve into a quasi-nation-state, and convert power. The leveraging ability is bi-directional, for groups like Al-Qaeda and ISIS consume information and promulgate information to learn, grow and assert their dominance. (Nye, 2011)

As shown above, it is not about the number of resources possessed, rather it is the way those resources are leveraged. Furthermore, the ability to leverage resources is better when it is bi-directional, as exemplified by Al-Qaeda and ISIS. Both of these points are revisited in Chapter 6.

Power conversion is defined as, "getting from resources to behavioral outcomes." Power, like that of fragility, resides along a spectrum. Joseph Nye asserts that hard power exists on one end of the spectrum and soft power exists on the other. Tangible sources of power such as military force and money reside on the hard power end, while agenda framing, and persuasion exist on the other. Because power is spectral, overlap is common, particularly with regards to the instruments of its execution. That is, the resources associated with power production can be used in both hard and soft power strategies.

At any given time, states' power fluctuates in tandem with the global forces of the world. Economic power dwindled for many nations with the 2008 recession and then came back. Soft power has prevailed for the French since the Age of Enlightenment and remains prevalent today as the French language, in conjunction with English, is used in all documents issued by the United Nations Treaty Series. In fact, the University of Southern California's Center on Public

Diplomacy provides a global ranking of soft power, and in 2018 France was ranked second only to the United Kingdom. The United States continues to flex its hard power muscles in both the Iraq War and War in Afghanistan. This means of classifying power in terms of its position on a scale is useful in demonstrating the dynamic nature of power and understanding that power is not absolute.

The greatest overlap between power and antifragility is between antifragility and what Joseph Nye refers to as power conversion. Recall that power conversion is defined as, "getting from resources to behavioral outcomes."[85] According to Nye, "power resources are simply tangible raw materials or vehicles that underlie power relationships, and whether a given set of resources produces preferred outcomes or not depends on behavior in context."[86] The action portion of the term power conversion, or conversion, implicitly means the process to change or cause something from one form or another. What the end state of that conversion is, Nye contends, will be a state of desired or undesirable behavioral outcomes. In order to achieve a desired end state, both resources and a conversion strategy must be present. As an equation, power conversion would look like the following:

$$\text{Power conversion} = \text{state resources} + \text{state strategy}$$

Whereas the presence of resources is a measurable portion of the equation, the presence of a conversion strategy is where the nuance involving antifragility lies as state strategies do not appear out of thin air. They are cultivated over time. They fail, and as with any good strategy, learning from those failures is paramount. A state exercising smart power can effectively marshal the resources it has available to respond to a stressor and not only recover but get better. A state less adept is likely to recover from a stressor less effectively. Those that are effective in

[85] Nye Jr., Joseph S. *The Future of Power*.
[86] Nye Jr., Joseph S. *The Future of Power*.

utilizing a combination of both will achieve their desired end states or behavioral outcomes. That is, it is the ability of leaders and/or institutions of a state to be able to carry out the desires of the state, which in turn generates power. However, just because a state has power, does not mean it will achieve its desired outcomes. It simply means it is better able to achieve its desired outcomes.

State Resources

State resources are defined as, "stock or supply of money, materials, staff and other assets that can be drawn on by the state in order to function effectively."[87] Examples of state resources include natural resources, organizational resources, political resources, industrial resources, population, geographic size/position, national image, public support, and leadership. Additionally, state resources can be bifurcated into two types: hard power resources and soft power resources.

Hard power resources are typically those that are more measurable and quantifiable. Things such as military capacity and economic power. "A country's soft power can come from three resources: its culture (in places where it is attractive to others), its political values (when it lives up to them at home and abroad), and its foreign politics (when they are seen as legitimate and having moral authority)."[88] State resources are important because a state manifests its strategies, beliefs, and interests through these means of power, and how well a state is able to convert those means of power is crucial to its place in the political pecking order. But a word of caution on resources: "Whether power resources produce a favorable outcome depends upon the context. For example, having a larger tank army may produce military victory if the battle is fought in the desert, but not if it is fought in swampy jungles such as Vietnam."

[87] Nye Jr., Joseph, S. *The Future of Power*.
[88] Nye Jr., Joseph, S. *The Future of Power*.

What happens to states that are not endowed with certain resources or when resources are lost or squandered? States might also borrow from or and lean on allies and partners for resources and capacities. This is demonstrated through things like mutual defense treaties and the inclusion in international organizations and institutions.

State Strategies

A state strategy is defined as how a state manages its resources towards the means of the state's perceived ends. At the core of each state's strategy is the fundamental goal survival. Following this strategy comes that of one that purses specific domestic interests or ideation coalitions. Finally, a state is able to form a strategy that seeks to establish a specific regional or global order. State strategies, specifically good state strategies, should be multifarious. They should include military strategies, diplomatic strategies, economic strategies, and social/cultural strategies. Strategies provide a roadmap for the provisioning of resources when those resources are threatened or face uncertainty. With the increase in uncertainty, threats are increasingly harder to recognize and are often unpredictable in time and scale. Furthermore, it is not possible to prepare and respond to all imaginable threats effectively and especially cost-effectively.

It is important to note, that the model developed in the next two chapters does not capture power conversion to the level of detail of state resources and state strategy are differentiated or even recognized. Similar to the agility attribute, these two concepts were "black boxed" in the agent attribute called power conversion. Ultimately, the black boxing of this attribute does not diminish the importance of this distinction for future work salient to this topic. Because of the importance of power conversion and applicability to antifragility, it is the second propensity variable of the agent in the model presented in Chapter 4. Instead, the state is endowed with a level of power that allows it to absorb a shock as it is first encountered. This variable, called *performance* in the model, is another important source of antifragility in that it allows the state to absorb some level of intensity of the shock initially, allowing for the state to respond. Should the state not possess this then it can no longer embrace shocks in the international system. This concept is coded into the model such that when the agent has a performance value equal to or less than 0, it "dies."

LEARNING

State learning can be defined as a process of exercising a judgement based on an experience or some other kind of input that leads actors to select a different view of how things happen ('learning that') and what courses of action should be taken. Seth Kaplan, wrote, "everyone in the development field recognizes that learning is essential to development." Learning, however, comes in many different forms, through a variety of processes and at varying rates.

There are many learning theories that have helped the study of politics. There are four of these. The first came from Deutsch (1963) who incorporated it in his relatively rationalist decision-making theory. Learning theories moved into psychological and sociological processes and motivations. Herbert Simon used his psychology background to investigate the behavioral patterns of organizations by exploring how organizations move beyond individuals' limitations by building structures that guide behavior. He was quick to point to the limits of rationality, the incompleteness of knowledge, and the organization practices imposed on individuals. This emphasis on the limits of rationality echoes the works of George Shackle and Nassim Taleb reviewed earlier in this chapter. Even cybernetics and cognitive psychology have informed international relations approaches to decision making for decades in John D. Steinbrunner's *The Cybernetic Theory of Decision.*

Robert Jervis's 1976 article, *Perception and Misperception in International Politics*, is tied to state learning in that it demonstrated how perception and misperception influence actors in the international system. Ernest Haas and Peter Haas's *Learning to Learn* catalogs the features of organizations that have successfully learned to improve their programmatic activities for environmental management in order to provide an example of organizational design for encouraging effective governance after the Cold War. Their approach was different because of their avowedly constructivist stances, focusing on shared beliefs that inform practices.

The field of psychology is also relevant to the discussion on state learning when considering types of learning. Skinner's 1974 idea of behavioralism assumes the learning is passive and will be shaped through positive or negative reinforcement. For him, learning is defined as a change in behavior. Cognitivism focuses on what happens in the mind such as thinking and problem-solving. New knowledge is built upon prior knowledge and learning needs active participation in order to learn. Changes in behavior are observed, but only as an indication of what is taking place in the learner's mind. Skinner uses the metaphor of the mind as a computer. That is, information comes in, is processed, and learning takes place. Finally, constructivism presents learning as being an active, contextualized process of constructing new knowledge rather than acquiring it. The learner brings in past experiences and cultural factors to a current situation and each person has a different interpretation on the knowledge process. Here, Taleb and Treverton's variable of history of surviving past shocks relates directly to the work of Skinner. The state, just like individuals, must constantly update itself through learning, adaptation, and incremental enhancement.

However, it is important to point out the difference in state learning and societal learning. According to Kaplan, state or societal learning differs from individual learning in four ways. First, state learning involves a different type of knowledge than individual learning. Individual learning knowledge is individual based; whereas the knowledge of state learning is knowledge that is group or organization based. Additionally, the "know-how" factor must be exponentially multiplied at a state level of learning. For example, states need a large group of administrators who can make their organizations work well. Second, states must learn from experience and develop new institutions that help them solve collective action problems. This concept echoes the thoughts of Markey-Tower discussed earlier when he commented that institutions which order our socioeconomic systems are in constant, evolutionary flux. Third, states need to find ways to attract and retain knowledge within their borders. Finally, states need feedback loops that improve how systems work. In other words, states must improve policies when they don't work which requires understanding where existing policies do not live up to expectations and what can be done about it. The notion of feedback loops as it pertains to antifragile systems is discussed in greater detail later in the chapter when examining the work of Johnson and Gheorghe. What is, then, the process by which states learn?

States learn by trying out new ideas and methods, choosing those that work, discarding those that do not work, and spreading the best methods as widely as possible. Success, however, is dependent upon the quality of the encompassing institutions (government in this case), organizations doing the experimenting, infrastructure, and feedback loops judging performance.

State learning that best fits an antifragile state is one that implements the Fail Fast Principle. Together, four design principles of the Fail Fast Principle isolate local failures before they propagate and cause systemic failure The Fail Fast Principle presents one operational principle to quickly remove exploitable vulnerabilities and explains how systemic failure can occur in a complex adaptive system even when no parts fail. In summary, while individual learning is critical to overcoming societal difficulties, state learning is just as critical as it forms the foundation by which states make future decisions regarding both its own domestic policies and foreign policies. To achieve this, states must first make sense of their environments.

To help structure thinking about learning, let us consider the five domains of the world as described by the Cynefin framework.[89] Developed by Kurtz and Snowden, the Cynefin Framework is a sensemaking framework that provides the user a context to think through the details of a particular situation, classify it and understand the appropriate response to make the most of the situation. The first domain is known as the Obvious or Simple domain. Here, the relationship between cause and effect is well known. The next domain is known as the Complicated domain whereby things are categorized as knowable. That is, while we do not immediately know what is happening, we can analyze the situation and come to a conclusion of what must be done. Next, the Complex domain is one characterized by items that we are not able to determine what will cause a particular result. The best course of action is to conduct experiments and check if any or all takes us in the correct direction. The Chaotic domain is one characterized by incoherence and an unstable situation. The time to experiment or probe does not exist since the situation is dire and action is necessary. Finally, the Disorder domain is the domain whereby anything whose domain has not been determined resides.

Equally important to the various domains is the movement through these domains. To move clockwise, from chaotic through complex and complicated to simple, knowledge increases. When there is a buildup of biases, complacency or lack of maintenance, a catastrophic failure can occur. Conversely, there can be a counterclockwise movement through the framework as knowledge is lost or forgotten or new generations challenge the status quo.

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[89] Snowden, David J., and Mary E. Boone. “A Leader's Framework for Decision Making.” Harvard Business Review, November 2007. https://hbr.org/2007/11/a-leaders-framework-for-decision-making.

While some have criticized the Cynefin framework for being difficult and confusing, it has enjoyed many applications across a variety of fields. Areas such as emergency management, network science, product development and supply chain management have all utilized the Cynefin framework. Stephen Geron's thesis, 21*st* *Century Strategies for Policing Protest: What Major Cities' Responses to the Occupy Movement Tell Us About the Future of Police Responses to Public Protest*, examines how the experiences of New York City, Oakland, Portland, and Dallas during the Occupy Movement tell us about using emergent strategies for policing protest in the twenty-first century. From his research, Stephen was able to provide strategic recommendations for city and police leaders in dealing with protests by utilizing the Cynefin framework. Cities that learn more effectively about the problems they actually face can better respond in constructive ways.

MODELS OF ANTIFRAGILITY

This section explores models of antifragility by drawing on its usage and characterization in a number of contrasting disciplines in order to synthesize a framework for understanding this concept in International Relations. The majority of these models deal with physical systems that rely on a variety of modeling techniques for execution rather than one singular technique. Additionally, each model is narrowly focused on one aspect of antifragility rather than an attempt to model antifragility as a whole. Nonetheless, the results and implications of each provides insights into antifragility, demonstrates a need to further study this topic, and influences the model presented in this dissertation.

Kennie Jones's piece, *Engineering Antifragile Systems: A Change in Design Philosophy,* outlines seven descriptions of ongoing research that adopts the philosophy of "new methods producing systems that can adapt to functionality and performance to meet the unknown." [90] As Jones points out, current methods of design requirements by design produce fragile systems; therefore, Jones proposes that systems should be designed to be antifragile in order to be designed to access the environment in real-time operation and adapt in response to current events that need not be completely known at design. One example in Jones' paper is that of the ongoing research areas conducted by the National Aeronautical Space Association (NASA) to design cognitive cyber-physical systems that can learn from their experience, adapt to unforeseen events they face in their environment, and grow stronger in the face of adversity.[91] From Jones' work and most pertinent to the model, comes an emphasis on learning, experience, adaptability, growing stronger, and stress.

Furthermore, Jones' piece calls for a change in design philosophy that enables systems to learn to perform in the face of the unexpected and improve performance beyond what is anticipated. In other words, he is calling for a change in design philosophy that will produce antifragile systems, demonstrating that continuing conventional design methods of specifying requirements that produce systems to perform as expected in an anticipated environment may not solve these unsolved problem sets. Overall, the Jones' work underscores the call for adapting and integrating antifragility into system design, similar to the call for adapting and integrating antifragility into International Relations. What would this call for adaptation and integration look like though?

Recognizing that the twenty first century is defined by many technical and social hazards, John Johnson and Adrian V. Gheorghe's *Antifragility Analysis and Measurement Framework*

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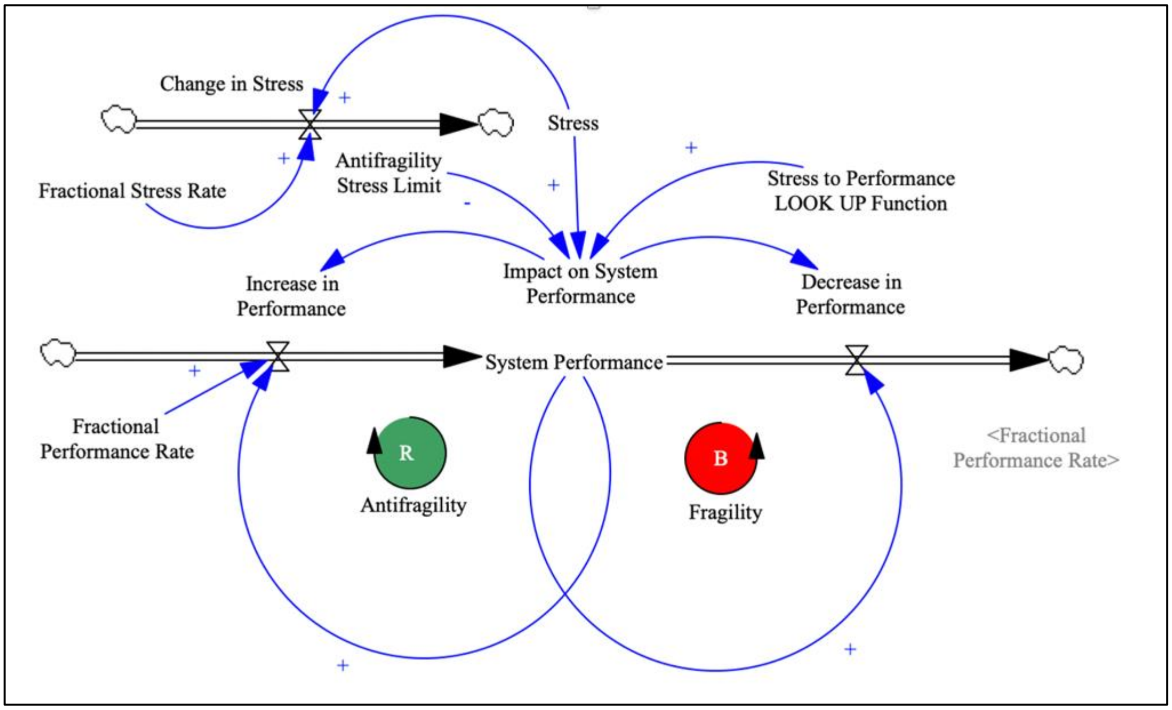
[90] Jones, Kennie H. "Engineering Antifragile Systems: A Change in Design Philosophy." *Procedia Computer Science* 32 (2014): 870–75. https://doi.org/https://doi.org/10.1016/j.procs.2014.05.504.
[91] Jones, Kennie H. "Engineering Antifragile Systems: A Change in Design Philosophy." *Procedia Computer Science* 32 (2014): 870–75. https://doi.org/https://doi.org/10.1016/j.procs.2014.05.504.

Systems of Systems presents an antifragile system simulation model and proposed framework for analyzing and measuring fragility based on a system of systems concept. Notably, the proposed framework reduces a multidimensional concept of fragility into a two-dimensional continuous interval scale. Johnson and Gheorghe represent antifragile systems using a stock and flow structure from systems dynamic modeling, representing the mechanics of a system that can result in either an antifragile, robust, or fragile state.

Stress and performance are represented by the box variables, system stress and system performance, respectively. Stress is increased by the variable "change in stress" and has an impact on the "system performance." System performance may either increase (resulting in antifragility) or decrease (resulting in fragility) and be represented by reinforcing or balancing loops that are important characteristics of the model. Overall, they demonstrate the delicate balance between fragility and antifragility and demonstrate resilience when balanced. Above all, the model presented in Johnson and Gheorghe's paper heavily influenced my agent-based model in Chapter 4. In particular, the reinforcing or balancing loops are important characteristics of the agent. Additionally, system performance is replicated in my model through the "state performance" variable. Performance growth is caused by the increase in the rate of change in performance, and performance decline is caused by the negative impact of stress. Taleb's notion that the antifragile gets better with stress while the fragile get worse under stress is evidenced in the work of Johnson and Gheorghe's system dynamics model. (Figure 2)

Figure 2: System Dynamics Model of Antifragility by Johnson and Gheorghe (2013)



Finally, Johnson and Gheorghe graphically represent the relationship between the impacts of stress on a system performance. All outcomes are known and intended when a system resides in the robust zone (yellow zone). That is, the system is functioning as it was expected to function given its design. Within the fragile zone (red zone), stress eventually overcomes the system and it rapidly declines into a failure state resulting in unintended outcomes or previously unknown failure states. Finally, all outcomes in the antifragile zone (green zone) were previously unknown and positive.

Perhaps most importantly, Johnson and Gheorghe identify a set of analytical criteria in order to determine where a system fits on the antifragility curve. Johnson and Gheorghe use a list from Jackson and Ferris (2012) that are based on domain expert analysis of ten case studies on system of system interventions intended to improve a system's ability to survive a threat. These criteria include entropy, emergency, efficiency vs. risk, balancing constraints vs. freedom, coupling, requisite variety, stress starvation, redundancy, non-monotonicity, and absorption. These criteria were already discussed in an earlier section.

In conclusion, the model presented in Johnson and Gheorghe's work serves as an important influence on the model presented later in this dissertation. First, the notion that states possess two loop types, fragile and antifragile, is reflected to a degree in the model presented in Chapter 4; however, it is what the system dynamic model lacks that influences the design of the model in this dissertation as much as what is has. Specifically, and perhaps most importantly, the Johnson and Gheorghe model lacks the details and subsequent explanation of the inner workings of the system's performance within the bigger system whose output determines which loop is more dominant. It is this gap, coupled with research on agility, state learning, and power conversion that has influenced the model presented later in this dissertation.

CONCLUSION

This chapter examined the applications of a disparate set of disciplines that demonstrate how the terms fragile, resilient, and antifragile relate to international relations, specifically states. In addition to examining the origin of these terms, the process by which organisms, systems and states become fragile and resilient is analyzed along with how they are quantified. Specifically, the OECD and FSI were examined which tell us little about what lies beyond resiliency.

Next, the ideas of Nicholas Nassim Taleb and Gregory Treverton were analyzed, revealing a parallel gap in their work similar to that of the OECD index and FSI. That is, Taleb and Treverton provide a static representation of their variables, do not quantify those variables, or provide the tipping points that push states from one category to another.

Finally, models of antifragility were introduced and explored for their valuable contributions to antifragility that might lend themselves well to producing a comprehensive model of state antifragility, including the work by Johnson and Gheorghe, which serves as the foundational basis for the model presented later in this dissertation.

Overall, three gaps were identified in the literature on state fragility. First, fragile states and resilient states are typically the only categories considered by scholars of international relations, leaving aside the potentially very important category of antifragility. Indices like the FSI and OECD provide a way to assess the vulnerability of a state to conflict or collapse, but do not include a measure of antifragility in which a state may benefit from conflict. The advantage of viewing fragility and resilience along a spectrum is that states become less binary, providing the opportunity to examine some of the nuances of states within the international system. Additionally, doing so can give greater flexibility in our understanding of states and state behavior. That is, states do not fit into binary-fragile or resilient-categories. They change over time, and it is the behavior change over time, rather than the final end state that is where interesting behavior occurs.

Second, the limitations of Taleb and Treverton’s work are such that they provide their readers with a seed and an intuition about antifragility of states, but they fall short of giving the readers the process by which states become fragile, resilient or antifragile. Furthermore, while they do provide five variables intended to reflect the presence of fragility/antifragility, they stop short of fully explaining how these variables might influence one another or how, together, they produce a fragile, resilient, or antifragile state. Instead, literature on learning, power conversion and agility provide a greater depth to how states might become fragile, resilient or antifragile.

As such, these variables are presented as the propensity variables by which states move along the spectrum of fragility-antifragility.

Finally, literature from the discipline of modeling and simulation provide readers with an orientation into how models may be used to gain greater insight into antifragility. In particular, the system dynamic model of antifragility from Johnson and Gheorghe provides a useful framework modeling for antifragility by providing their readers with a basic example of how the process of antifragility might occur from a system of systems approach. However, the work of Johnson and Gheorghe, though a useful starting point, does not provide insight into how the inner workings of the individual system. Furthermore, the model presented in their paper does not provide a great deal of detail or code by which the model might be replicated, examined, or even modified. The next chapter will provide a detailed overview of how the literature reviewed translates into an agent-based model of antifragility of states which will then be fully developed and explained in Chapter 4.

METHODOLOGY

"The goal of agent-based modeling is to enrich our understanding of fundamental processes that may appear in a variety of applications."[92]

There is an increasing interest in modeling and simulation across the social sciences that can be observed in both practice and academia, due to the many potential advantages inherit in this method (Gilbert and Troitzsch 2005; Meyer, Lorscheid and Troitzsch 2009; Reiss 2011; Railsback and Grimm 2011). As a first step in the process of scientific inquiry, it is important to understand the background and rationale for choosing to employ the methodology of modeling and simulation in general along with identifying the advantages to undertaking agent-based modeling versus some other technique.

The first section of this chapter provides an overview of the advantages of choosing to undertake the practice of modeling state antifragility, specifically referencing the works of Joshua Epstein and Railsback and Grimm. The focus of this chapter then narrows to specifically identifying the advantages of agent-based modeling as the best technique to addressing the goals of this study. Next, the chapter concludes with an examination of the limitations of using modeling and simulation in general and agent-based modeling in particular as a technique, though it was determined that the advantages far outweighed the disadvantages in the case of this study.

Next, this chapter provides with a high-level overview of the model presented in Chapter 4 to help orient the reader into the detailed discussion of the model and decision making that informs the model presented in the next chapter. Finally, the chapter concludes with an overall

[92] Axelrod R. (1997). Advancing the art of simulation in the social sciences. In ConteR.HegselmannR. TernaP. (Eds.), Simulating social phenomena (pp. 21–40). Berlin, Germany: Springer-Verlag.

research plan and methodology of the research. This section focuses specifically on providing a cohesive stepped approach of the entire dissertation.

ADVANTAGES OF MODELING AND SIMULATION

When deciding to undertake the arduous task of modeling a certain behavior or entity, one of the most frequently asked questions is "why model?" In the case of antifragility, there are relatively few explicit models of antifragility and none of state antifragility. Instead, Taleb and Treverton's Foreign Affairs article produced what Joshua Epstein refers to as an implicit model, or a model "in which the assumptions are hidden, their internal consistency is untested, their logical consequences are unknown, and their relations to data is unknown." [93] Implicit models, though useful in other ways, do not allow avail themselves to others to run additional experiments in order to test assumptions, confirm or challenge results, and modify the model; therefore, the construction of an explicit model is advantageous for further scientific inquiry into state antifragility. On the theoretical level, the model contributes to the literature on fragile states and state behavior as previously discussed in detail in Chapter 2.

Furthermore, undertaking an agent-based modeling approach allows International Relations scholars and practitioners the ability to explore complex problems by investigating how components of complex interactions, such as that of stress and a state, interact and how performance of states is sustained or changed through these interactions. The visualizations of model results in Chapter 5 provide evidence to suggest that the indicators of antifragility are important for state performance and survival.

As Joshua Epstein wrote, "…by revealing tradeoffs, uncertainties, and sensitivities, models can discipline the dialogue about options and make unavoidable judgements more

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[93] Epstein, Joshua M. "Why Model?" *Journal for Artificial Societies and Social Simulation*, 12, 11, no. 4 (October 31, 2008). https://www.jasss.org/11/4/12.html.

considered."[94] Simply put, what Epstein means is the act of making explicit tradeoffs, uncertainties, and sensitives through the practice of modeling makes you and others more considerate of the biases that are inevitably resident in any analysis. As a result, undertaking the process of modeling and simulation allows International Relations scholars and practitioners to experiment (e.g., unpack constructs, relax assumptions, vary construct values, add new features) in a controlled setting to produce new theoretical insights.

Once the "why" inquiry has been satisfied, the next natural question that arises in the modeling process is "what do you hope to predict?" This question is at best radically incomplete when it comes to model purposes. While prediction is a worthy pursuit in modeling in some situations, it should be noted that not all models are constructed for the purpose of prediction. In fact, Gilbert and Terna (2000) have stated that the reason why social sciences have not benefited from computer simulation as a methodological approach enough may be that the main value of simulation in the social sciences is for theory development rather than for prediction.[95] Joshua Epstein's article, "Why Model," provides sixteen reasons other than prediction to build models which are just as crucial to modeling as prediction. Epstein's reasons pertinent to this dissertation include the following:

1. Explain (very distinct from predict).
2. Illuminate core dynamics.
3. Discover new questions.
4. Challenges the robustness of prevailing theory through perturbations.

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[94] Epstein, Joshua M. "Why Model?" *Journal for Artificial Societies and Social Simulation*, 12, 11, no. 4 (October 31, 2008). https://www.jasss.org/11/4/12.html.
[95] Gilbert, Nigel, and Pietro Terna. "How to Build and Use Agent-Based Models in Social Science." *Mind & Society* 1 (March 2000): 57–72. https://doi.org/10.1007/BF02512229.

5. Reveal the apparently simple (complex) to be complex (simple). [96] (Epstein, 2008)

Each is discussed in greater detail with the addition of a discussion on a sixth reason to undertake modeling and simulation, generating theory.

Since the model in this dissertation is theoretical in nature, its fundamental purpose is explanatory in nature. That is, it does not seek to predict under what conditions antifragility will arise; rather, it offers an explanation of the processes that might produce antifragility through the use of agent-based modeling and shows how the presence of antifragility (and the ability to develop antifragility) can help explain histories of state behavior and experience (as applied in the case studies in Chapters 6 and 7). The model presented in Chapter 4 illuminates the core dynamics of state antifragility by taking the system performance "black box" presented in in Figure 2 of Johnson and Gheorghe's model and using Taleb and Treverton's five characteristics of state antifragility (now propensity variables) to inform that black box and adapt it to the context of states. Though some of these black boxes are then black boxed again by their variable definitions, they do provide greater detail and insight into the mechanics and types of characteristics that give rise to antifragility. This type of model allows scholars and practitioners to explore intuitions about antifragility and its development, as well as the consequences of fragility, resiliency, and antifragility. Among the resultant insights discussed in more detail in Chapter 5, the model shows first how important antifragility can be for state power and state survival. Second, the model shows that an antifragile state (or a state seeking to become or retain antifragility) may have incentives to engage in shock-seeking behavior with important (and potentially destabilizing) consequences for the international system. Both of these points are discussed in greater deal in the subsequent sections of this chapter.

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[96] Epstein, Joshua M. "Why Model?" *Journal for Artificial Societies and Social Simulation*, 12, 11, no. 4 (October 31, 2008). https://www.jasss.org/11/4/12.html.

In conjunction with the last point, the agent-based model presented in this dissertation allows us to illuminate the core dynamics of what makes a state fragile, resilient, or antifragile. Chiefly, one critical aspect of how states become antifragile comes from understanding how states learn from the shocks they experience. While the original Taleb and Treverton (2015) paper focus on only having a history of experiencing past shocks, the construction of a theoretical agent-based model reveals that having a history of experiencing past shocks is irrelevant if the state fails to learn lessons of that history. The case study presented in Chapter 6 focusing on the second Iraq War demonstrates that how crucial a lack of learning by the United States from their previous involvement with guerilla type warfare against insurgences in the Vietnam War had devastating consequences for the US military as they fought an insurgency in the deserts of Iraq and hills of Afghanistan roughly three decades later. To summarize, while having a history of experiencing past shocks does not guarantee learning, these experiences, as volatile as they may be, can be reimagined as opportunities for learning through the lens of antifragility.

Another example of how core dynamics of antifragility are illuminated through this agent-based model is evident in the model when examining how quickly states adapt to overcome shocks. That is to say, the length of the state's recovery period after it has encountered a shock or stress matters to not only the fragility, resiliency, or antifragility of the state, but also its survival. If the recovery period of a state is too slow, then another shock may come along during that recovery period, causing accelerated cascading effects of degradation. Again, we can look to the Soviet Union during the period of the latter half of Cold War in which the Soviet Union was entangled in a failing conflict in Afghanistan while simultaneously trying to keep pace globally with the United States. Then in 1986, the Chernobyl nuclear accident happened, arguably undermining public confidence. Finally, efforts at reform produced complex unintended consequences that undermined the system. In order to capture this important observation, the agent in model presented in Chapter 4 includes variable called *recoveryperiod (p)*. The recovery period informs how quickly or slowly a state recovers from experiencing a shock, in conjunction with the magnitude of the recovery experienced per period (m) which is dependent upon the type of state (fragile, resilient, or antifragile). As noted in Chapter 2, if the total recovery (*pm)* is less than its loss from shock then a state is fragile, for resilient states the total recovery *pm is equal to the performance loss from the shock*, and for antifragile states *pm* is greater than the performance loss from the shock. Chapter 5 will examine how (and sometimes in non-linear ways) the *recoveryperiod* variable influences the length of life of the state in the simulation.

Next, the creation of the agent-based model in this dissertation should lead to new questions, helping highlight the relevance of asking questions about antifragility when seeking to understand state behavior. As Epstein writes, “it’s the new questions (e.g., Hilbert’s Problems) that produce huge advances, and models can help us discover them.”[97] One of the most intriguing new questions this work reveals in international studies involves the theoretical relationship between the state and anarchy. The model in this dissertation offers a partial (conditioned by circumstances) challenge to the robustness of prevailing theory in the field of International Relations, specifically as it relates to the theoretical tenet that states seek to temper anarchy (Waltz, 1979). If a state is (or believes itself to be) antifragile, and antifragile things benefit from disorder, then the state will have an incentive to maintain a level of disorder or anarchy in its environment in order to maintain and benefit from its antifragility. The case study

[97] Joshua Epstein, Why Model? Retrieved From: http://jasss.soc.surrey.ac.uk/11/4/12.html

presented in Chapter 7 on the great power competition between the United States and China in the Indo-Pacific suggests that China deliberately probes the international community by actively operating just below the threshold for what the international community might call a shock. From the perspective of the United States, China's activity is a qualifies as a stressor in the Indo-Pacific region. The perceived stress of this is to the benefit of the Communist Party of China (CCP) in that they learn from the response, or lack of response, from their adversaries. The inclusion of antifragility into the scholarly debates and dialogue on state fragility and the tempering of anarchy, may, by the very nature of antifragility, reveal that tempering anarchy is not always advantageous to a state if it is able to process that anarchy in a way that benefits the state in the long run. Antifragile states have incentives to seek out disorder, instead of incentives to temper it.

Therefore, the model in this dissertation challenges the robustness of prevailing International Relations theory by questioning the central tenet of one of its most prevalent theoretical schools. That is, states seek to temper anarchy in order to survive, but should they? Does this central belief about how states behave distort our understanding of states, their behavior, and the international environment? By tempering anarchy are states diminishing their opportunities to encounter shocks and learn from those shocks, ultimately to their own detriment? Can states actually benefit from just the right amount of anarchy? By using an agent-based modeling approach to explore state antifragility, answers to these new questions may be revealed which enrich the debate on the absolutism of a Realist approach by demonstrating that states can in fact gain from a certain amount of anarchy. This could even offer an alternative rational explanation for war that is related to the commitment problem. If state leaders believe that their state is antifragile, they may choose to gamble on war despite what would seem to be poor odds and high costs precisely because they hope to gain from disorder.

Additionally, modeling helps to reveal the apparently simple (complex) to be complex (simple). As this agent-based model is both theoretical and one of the first of its kind, one of the main design goals was to keep the model as simple as possible, and then expand upon that simplicity in future iterations of the model. This statement is evident in the model presented in Chapter 4 through the design choice to model one agent (a single, state) and shocks in the environment, rather than modeling state on state interaction. By modeling the internal process of state antifragility within a single state and its interaction with shocks, the model accomplishes two things. First, the model stays within the scope of addressing one of the main criticisms of the literature on antifragility in Chapter 2. That is, Taleb and Treverton (2015) provide us with a list of potential indicators of state antifragility, but not the process by which states become antifragile. Johnson and Gheorghe (2012) give us a system of systems approach of the process by which systems become antifragile, but do not explain the inner system's performance process. Second, modeling a single agent with individual shocks over some period of time, considers Epstein's sixteenth goal of modeling for reasons other than prediction. Learning more and more about antifragility, revealed that Taleb and Treverton's five characteristics of state fragility which seemed qualitatively simple on the surface, could very quickly become quantitatively complex. Informed in part by this model along with the work of Taleb and Treverton, the simple black box of the inner system presented in Johnson and Gheorghe's model became more complex in this dissertation's model. Finally, modeling a single state provides the most general set of results, applicable not merely to the shocks states create for each other, but to the many other shocks which states face from other sources. For instance, the recent Covid19 pandemic challenged states around the world, and likely drove the defeat of some governments and presidents in elections. Its economic, political, and geopolitical impacts will be felt for years. But as of this writing there is little evidence that this shock was intentionally caused by a state. Analysis of the impact of shocks on a single state is also an essential precondition for accurate theorizing about strategies taken on by multiple states in a strategic interaction that includes consideration of the relative levels of (anti)fragility of each state.

Finally, modeling can be used to generate theory. According to the chapter, *Ontology, Epistemology, and Teleology for Modeling and Simulation*, found in the book, *Modeling and Simulation as a Theory Building Paradigm*, theory can be captured as model, which can then be implemented as a simulation. According to the chapter's authors, "the main objective is to generate theory, from existing theory, that can explain a phenomenon of interests by making explicit what the phenomenon is and how it works. The applicable phenomena, as mentioned, are those that have no forms of being measured, non-physical, no direct access to data, and due to these characteristics, multiple and often competing theories that can attempt to provide an explanation. As a form to formalize the process and gain insight into these phenomena, M&S is presented as the conduit to develop the theory."[98]

As the authors exclaim, the method on which a solution is based and the theory from which the method is derived should be the emphasis in scienced based disciplines. In other words, solutions are applied to solve problems, but the emphasis should not lie in the solution itself but rather other areas of emphasis such as the method on which the solution is based and the theory from which the method is derived.

[98] Diallo S.Y., Padilla J.J., Bozkurt I., Tolk A. (2013) Modeling and Simulation as a Theory Building Paradigm. In: Tolk A. (eds) Ontology, Epistemology, and Teleology for Modeling and Simulation. Intelligent Systems Reference Library, vol 44. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-31140-6_10

Advantages of Agent-Based Modeling

With a variety of modeling techniques to choose from, understanding the advantages of using agent-based modeling to investigate state antifragility set is imperative for the choice of modeling technique and simulation application influences the study and outcome. Recall from Chapter 1 that agent-based modeling assumes that the world can be usefully modeled using computer-generated agents, an environment, and a description of agent-agent and agent-environment interactions. Though agent-based models possess many advantages, building a model of state antifragility is a good choice for three main reasons.

First, with Taleb and Treverton's work as the starting point for the adaptation and integration of antifragility into the literature on international relations, an explicit model that captures the properties of antifragile states and how they work together must be produced. Agent-based modeling lends itself well to achieving this end state because it is an extensible practice. That is, agent-based models can be incrementally advanced and refashioned to answer questions and produce new questions to pursue. Through the use of agent-based modeling, others are invited to modify and adapt parameters, variables, and agents in order to produce new insights and challenge the assumptions of the previous model, making for a more flexible type of modeling to allow for this modification and adaptation by model designers and users. Indeed, the analysis in Chapter 5 follows just this path, beginning with a baseline model (World A) in which states do not lose or gain antifragility, but always retain the same level (e.g., always antifragile or always fragile), and then extending to a second model (World B) where the experience of interacting with shocks informs a process of learning and forgetting that can move states either towards or away from antifragility.

Second, agent-based modeling is a holistic modeling approach that permits multiple questions to be answered across a complete system. In the case of the model in Chapter 4, two objectives are achieved in order to advance study of antifragility. First, the propensity variables of state antifragility are defined, refined, and operationalized. Second, the variables are constructed in an agent-based model in such a way that the user may modify the values of the variables with ease in order to produce results for a number of various scenarios including the scenarios presented in the case studies chapters or even at extreme values under extreme conditions to test the limits of the model.

Finally, agent-based modeling is particularly well suited to understand both individual-level behavior and aggregate-level behavior by allowing the modeler to pursue a bottom-up rather than top-down approach. By doing so, the modeler can examine data and discover what relationships emerge from the data, rather than beginning with presumptions about the relationship and disaggregating. For the purpose of studying antifragility and state antifragility, a topic nascent in its application to the field of International Relations, a bottom-up approach is preferred because the piecing together of systems in this way gives may give rise to more complex systems through emergence. The model presented in this study is one that models the individual state, allowing a greater understanding of what transpires when it interacts with an environment containing various types of shocks to produce, maintain, or destroy a fragile, robust or antifragile state. Most importantly, adopting an agent-based modeling approach to study state antifragility is powerful because testing the real-world systems by deliberately introducing shocks into the environment to see how states respond to and recover from is not feasible.

DISADVANTAGES OF MODELING AND SIMULATION

For the purpose of investigating state antifragility, I determined that benefits of undertaking the modeling and simulation process outweighed the limitations of the modeling and simulation approach; nonetheless, it is important to identify those limitations.

The Institute of Industrial and Systems Engineers (IISE) provides a succinct list of disadvantages to using modeling and simulation. According to Sokolowski and Banks (2009), the IISE cites the need for special training to build models, difficulty in interpreting the results, cost in money and time, and inappropriate use as the four disadvantages of undertaking modeling and simulation.[99] While modeling and simulation has become more accessible to those without a mathematical or engineering background in part due to the simulation software used to program a model, the process that one must follow to be able to adequately address the requirements of professional organizations like the Institute for Electrical and Electronics Engineers (IEEE) or the Institute for Operations Research and the Management Sciences (IORMS) as the leading associations for operations research, analytics, and electronic engineering and electrical engineering can be difficult for those who do not claim these fields as their home. Thus, engineering management practices and processes such as model formulation, model translation into a programming language, and verification and validation to name a few, must be understood in order to undertake this approach. For those who focus on the social sciences, these standards may not be applicable to their methodology, and thus require substantive learning to integrate into their method of scientific inquiry. Since the model in this dissertation is theoretical in nature, the verification and validation processes are different than if the model had not been theoretical. For example, we are now only identifying and searching for examples of state

[99] Sokolowski, John A., and Catherine M. Banks, eds. *Principles of Modeling and Simulation: A Multidisciplinary Approach*. Hoboken, NJ: Wiley, 2009.

antifragility; therefore, comparing the model to a real system is difficult since we are only beginning to define that system. Model validation is discussed in depth in the validation section below. In particular, I discuss the face validity of the model, and also look at the validity of the assumptions, and then later (in the case studies) I examine whether the behavior of the model matches the behavior observed in the cases.

Next, difficulty in interpreting the results of a model and simulation can occur when an observation may be the result of system inter-relationships or randomness. I attempt to address this issue in the analysis that forms the basis of Chapter 5, by analyzing a very large number of model runs with all model variables varied systematically in order to examine the conditional effects of the variables, with results summarized in a series of graphics. None the less, there are potential issues (i.e., lack of IID) [100] to worry about inferences drawn from model output. Since this work is theoretical in nature, the data used to inform the model is notional; however, this detail does not invalidate the need to conduct this exploratory research as key intuitions about antifragility can be ascertained through the use of notional data in the simulation model and validated against the existing literature on antifragility.

Finally, the modeling and simulation process is often a time consuming and expensive process. In some instances, a simulation may not be sufficient enough for the problem, and thus, consumes time and effort for nothing. Finally, inappropriate use of modeling and simulation when an analytical solution is best is the final disadvantage to undertaking the modeling and simulation process. In the case of this dissertation, I determined that due to the nascency of topic of state antifragility that the advantages of an agent-based modeling and simulation approach far outweighed any of the disadvantages. An agent-based modeling approach was a particularly

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[100] Maria, Anu. "Winter Simulation Conference." In *Proceedings of the 1997 Winter Simulation Conference*, 7–13. NW Washington DC: IEEE Computer Society, 1997.

well-suited analytical approach to addressing state antifragility for all of the reasons mentioned in the previous section.

THEORETICAL IMPLICATIONS FOR INTERNATIONAL RELATIONS THEORY

A related goal in producing an explicit, agent-based model of state antifragility is to use the concept of state antifragility to advance International Relations theory. To date, antifragility has mostly been an academic concept with little to no practical application. For this reason, creating an agent-based model of state antifragility rather than relying on models based in other disciplines provides the groundwork for integrating the nascent topic of antifragility in our field. As such, there are three primary benefits of developing theory through simulations as described by Davis, Eisenhardt, and Bingham (2007). The authors outline these when they write,

> First the computational rigor of simulation forces precise specification constructs, assumptions and theoretic logic that creates strong internal validity. Second, the process of simulation creates a computational laboratory in which researchers can systematically experiment (e.g., unpack constructs, relax assumptions, vary construct values, add new features) in a controlled setting to produce new theoretical insights. This experimentation is particularly valuable when the theory seeks to explain longitudinal and processual phenomena that are challenging to study using empirical methods because of their time and data demands. Finally, Simulation is well suited to theory development related to nonlinear phenomena, such as tipping points, feedback loops, and thresholds and catastrophes, and asymmetries.[101]

More specifically, this dissertation's use of a theoretical, agent-based model paves the way to generate a theory of state antifragility in International Relations. As a result, this theory

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[101] Davis, J., K. Eisenhardt, and C. Bingham. "Confucius Institutes: The Growth of China's Controversial Cultural Branch." *Academy of Management Review* 32, no. 2 (April 1, 2007): 480–99. https://doi.org/10.5465/amr.2007.24351453.

can be used to supplement weaknesses in explanatory power of current theoretical paradigms (i.e., Realism) when exploring why some states fair better under stress than others, ceteris parabus, or more specifically, how some states can benefit from stress whereas others do not, ceteris parabus.

First, the identification of the three propensity variables of state antifragility, enables International Relations scholars and practitioners to anticipate who the next "winners" and "losers" might be in the next global crisis or conflict. To do so, scholars and practitioners are encouraged to include antifragility in their consideration of possible state outcomes on the spectrum of fragility in indices such as the FSI or OECD index.

Second, as evidenced by the results of the experiments in Chapter 5, how well a state learns (or how forgetful it is) directly impacts its capacity to be antifragile. Having knowledge of how well a state learns (or forgets) can help us monitor the health and wellbeing of a state and anticipate necessary interventions or aid in the face of an impending crisis.

Third, the application of case studies in Chapter 6 and Chapter 7 provide evidence to suggest that challenges the prevailing assumptions about the violent extremist organizations in the War in Iraq and the first of China in the Indo-Pacific. Specifically, the case study on the United States and Al Qaeda in Iraq (AQI) during the War in Iraq (2003-2011) revealed that violent extremist organizations can possess the same three propensity variables of states and how two of those propensity variables, learning and agility, benefited AQI. A lack of these same two variables, however, hindered the most powerful military in the world against this insurgent force. Overall, this case study questions the notion in Realism that though states are the principal actor in international relations, other bodies exist whose power is limited. In the case of AQI and the

United States in the Iraq War (2003-2011), AQI proved to be more powerful than the United States for a certain period of time.

Additionally, the case study of the great power competition between United States and China illuminates the potential weaknesses of China as this great power competition evolves in the Indo-Pacific. In particularly, China's centralized governance structure and lack of history of surviving past shocks may play a role in China becoming more fragile over time. By traditional measures of power, both military and economic, China outperforms the United States. However, when examined through the lens of antifragility, two key variables provide International Scholars and practitioners with potential weaknesses of China that may render it more fragile than previously considered.

Finally, among the resultant insights discussed in more detail in Chapter 5, the model demonstrates how important antifragility can be for state power and state survival. It also shows that an antifragile state (or a state seeking to become or retain antifragility) may have incentives to engage in shock-seeking behavior with important (and potentially destabilizing) consequences for the international system. At the core, this implication challenges one of the fundamental tenants of Realism by suggesting that states may not benefit from tempering anarchy but may in fact seek out anarchy as means to become antifragile or maintain its antifragility.[102]

THEORETICAL LIMITATIONS ON IMPLICATIONS FOR INTERNATIONAL RELATIONS THEORY

Just as there are benefits to using simulation to develop theory, so too exist limitations. Again, referring to the work of Davis, Eisenhardt, and Bingham (2007), one primary limitation is external validity. The authors write, "simulation eliminates complexity in order to focus on the

[102] Realism argues that states in an anarchic world seek to temper anarchy.

core aspects of phenomena and so uses competitional representations that are often stark. The result may be an overly simplistic and distant model that fails to capture critical aspects of reality."

This same limitation extends to the work in this dissertation specifically as it pertains to the implications for International Relations theory. The appeal of Realism is that it is applicable across a broad range of scenarios over time to where it is now considered a definitive explanation of state behavior in International Relations. Certainly, there are instances that exist outside of what Realism can explain, however that does not make Realism any less useful. This same argument can be made for using modeling and simulation to develop theory. Since a model is an abstraction of some complex behavior, it does run the risk of failing to capture critical aspects of reality. Furthermore, there are instances where the model may not produce results consistent with real world behavior or outcomes. Neither of these invalidates the model. The model is still useful; however, it is understanding under what conditions the model is most useful is key. All of this is to say, "all models are wrong, but some are useful."[103] Enhancing the usefulness of this model as it pertains to theory development in International Relations can be done through the addition of using real world data, rather than theoretical data, to inform the variables. Additionally, the application of the model to additional case studies can be executed to further enhance the model's validity.

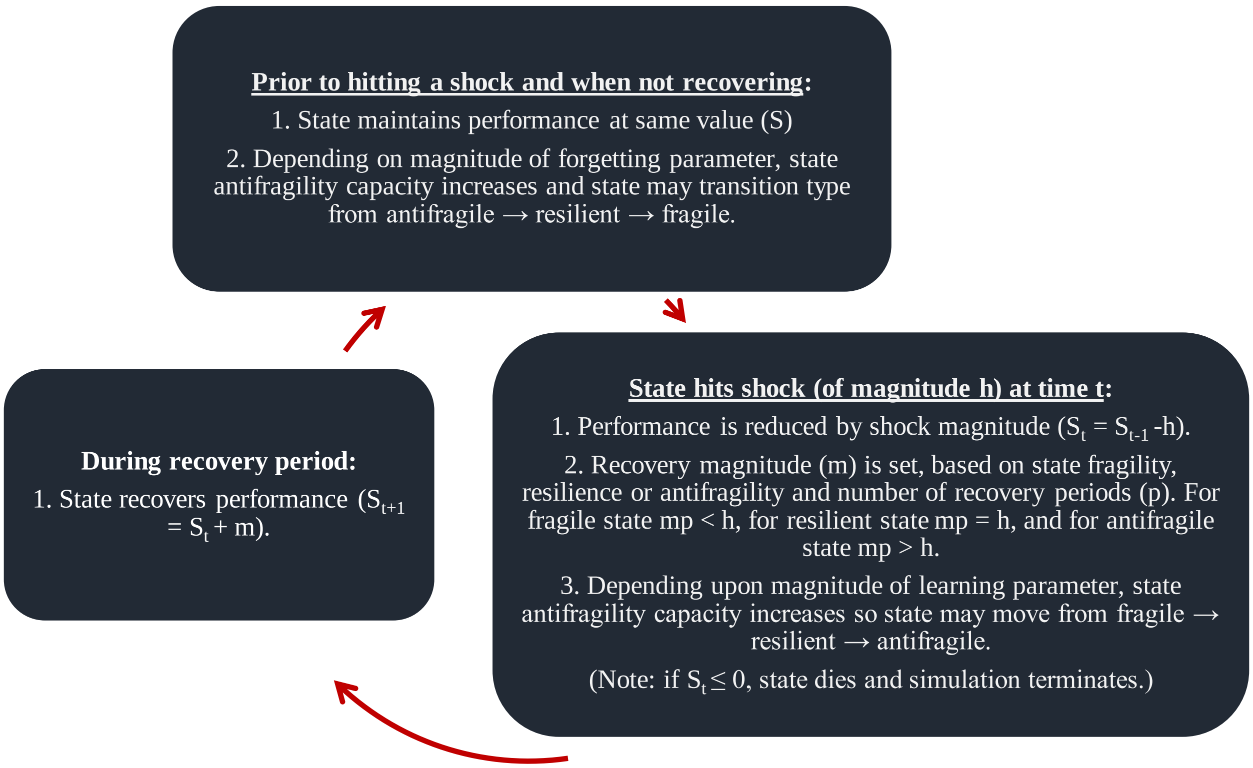
HIGH LEVEL OVERVIEW OF THE MODEL

Now that the justification for undertaking an agent-based modeling and simulation approach to answering the research question of this dissertation has been presented, a high-level

[103] Box, G.E.P. (1976), "Science and statistics, Journal of the American Statistical Association. 71 (356): 791-799, doi: 10.1080/01621459.1976.10480949.

overview of the model presented in the next chapter is provided to orient the reader into understanding the model, how to explore it, and to see what might be learned from it.

Figure 3: Overview of Model Process



In order to understand the extent and limits of the limited existing antifragility research and assumptions, and in order to answer the central research question, *why are some states more antifragile than others*, an agent-based model of state antifragility was constructed. As already hinted at above, the model focuses on the performance and life of a single agent moving through an environment that contains shocks of various magnitudes. The key characteristic of the state is whether it possesses antifragility, which impacts the extent to which the state is able to get better, stay the same, or get worse after encountering a shock.

States begin with a level of performance (S) and an antifragility capacity variable which (depending upon which thresholds for the variable they cross leads the state to be classified as fragile, antifragile, or resilient. Until a state hits a shock, the state will maintain the same performance value (S). However, as the literature on antifragility reviewed above emphasizes, lack of experience with shocks can render a state more fragile. Hence over time (and conditional upon the magnitude of the forgetting parameter) state antifragility capacity may degrade, with initially antifragile states potentially transitioning to resilient states, and ultimately to fragile states if no shocks are encountered for a prolonged period relative to the magnitude of the forgetting parameter.

When a state encounters a shock (h) in a time period (t), several things happen. First its performance is immediately degraded. Performance is reduced by shock magnitude ($S_t = S_{t-1} - h$), and if state performance drops below zero ($S_t \leq 0$), the state will die and the simulation terminates. Then the parameters for the recovery process are set. Recovery magnitude (m) is set, based on state fragility, resilience or antifragility and number of recovery periods (p). For fragile state the total recovery experienced is less than the hit from the shock ($mp < h$), for resilient states recovery will eventually return the state to its prior level ($mp = h$), and for antifragile states recovery will eventually lead to performance above the level initially possessed by the state ($mp > h$.) Hitting a shock may also allow a state to develop its antifragility capacity, rendering it better able to deal with future shocks. Thus, the third major event when a state hits a shock involves learning, modeled as an increase in the antifragility capacity variable. Depending upon magnitude of the learning parameter, state antifragility capacity increases, potentially moving a fragile state up to a capacity level that renders it resilient, or a resilient state up to a level of capacity that means it will be antifragile if it encounters another shock before this capacity degrades.

After hitting a shock, the state enters the recovery period. During each turn of the recovery period (p) state performance recovers by the recovery magnitude ($S_{t+1} = S_t + m$). At the conclusion of the recovery period, a fragile state will have recovered to a level of performance below its previous performance, a resilient state will have returned to its initial performance level, and an antifragile state will have recovered to a level of performance better than its initial performance. After the recovery period ends, a state will begin to once again begin to forget antifragility capacity (conditioned by the magnitude of the forgetting parameter) until it once more encounters a shock.

Informed by two key works on antifragility, the model aggregates Taleb and Treverton's five variables of fragility into three, original propensity variables-learning, power conversion, and agility. While an in-depth discussion of these variables was presented in Chapter 2 for identification and framing purposes, for the purpose of modeling state antifragility, the propensity variables discussed earlier in Chapter 2 are further aggregated into a different set of variables within the final model. This design choice was intentionally made for a number of reasons. First, recall from earlier that a best practice within modeling and simulation is to keep the model as simple as possible. That is, model only what is critical to understanding to answering your research question. The level of depth and complexity that each of these propensity variables could have brought to the model had the propensity to introduce a level of complexity to the model that violated the "keep it as simple as possible" best practice. By creating a new index to quantify the propensity variables, I risked adding a significant layer of complexity to the model. Furthermore, discerning the differences mathematically among these variables by weighting them added an additional layer of complexity that was not necessary to understand *why some states are more antifragile than others and the difference that makes*. Instead, a future iteration into these variables is more than sufficient to write another dissertation or research paper. In summary, the basic principles of the model were kept as simple as possible, and as a result, the modeling approach toward the construction of the agent-based model was consistent with the adage of "start simple and add incremental changes" to assure the model never became overly complicated. Hence, in the model, the core variables are those outlined in Table 4 below.

However, it is important to note that the research conducted in understanding the depth and dimensionality of the three propensity variables is not lost. While they are not explicitly modeled in the simulation model, each of these variables are captured in the variables that can be found in the final model. Table 4 below provides an evolutionary history of Taleb and Treverton's original variables to their final modeled state in the simulation model.

Table 4: Antifragile Variable Evolution

Taleb and Treverton Variables	Propensity Variables	Final Model Variables
1. Concentrated decision making 2. Political variability	*Agility*	Recoverytime, recoverymagnitude
1. Economic Diversity 2. Debt to Leverage Ratio	*Power Conversion*	Performance, capacity category of state (fragile, resilient, or anti-fragile)
1. History of Surviving Past Shocks	*Learning*	Percent-learn, percent-forget, recoverytime, capacity category of state (fragile, resilient, or anti-fragile)

In the final model, the variables *recoverytime* and *recoverymagnitud*e are defined as the amount of time it takes the agent to recover from a shock and the extent to which the agent recovers, respectively. These two variables directly correspond with the original definition of state agility, which recall from Chapter 2, is defined as both speed and magnitude with which states sense, respond, adjust, and adapt their strategies, as a function of changing circumstances.[104]

Next, recall that power conversion is defined as, "getting from resources to behavioral outcomes." According to Nye, "power resources are simply tangible raw materials or vehicles that underlie power relationships, and whether a given set of resources produces preferred outcomes or not depends on behavior in context."[105] It is important to note that resources come in many forms whether they be natural or monetary for example, and how economically diverse a nation is, is an indicator of the health of those resources. Performance, defined as the ability of a state to absorb a shock without dying, can be viewed in some ways as indicator of a successfully conversion of power. Additionally, a nation's debt to leverage ratio matters a great deal when it a nation needs to utilize its resources to deal with a shock. In the model, the performance variable is defined as that agent's ability to absorb a shock without dying

Finally, perhaps the most critical variable for antifragility is that of learning. State learning is primarily dependent upon experience, or as Taleb and Treverton (2015) describe a history of surviving past shocks. With each shock experience come the opportunity for a state to learn from that experience. The learning from the experience is not permanent. Learning may erode over time and lead to forgetfulness of the experience. How well a state learns or forgets directly impacts how well the state does or does not recover from encountering a shock and how

[104] Pragne, Christiane, and Loizos Hercaleous. "Agility.X-How Organizations Thrive in Unpredictable Times," June 2018.
[105] Nye Jr., Joseph S. *The Future of Power*. New York, NY: Public Affairs, 2011.

long it takes to recover from the shock. The better state is at learning, the more likely it is to recover better and faster than if it forgets the experiences of encountering shocks.

The primary key to understanding the model is that states vary in the way they respond to and recover from shocks in a multitude of ways. When the agent (a single state) encounters a shock in the simulation environment, its ability to deal with future shocks is affected, namely through the activation of one of two loops it possesses, a fragile loop and an antifragile loop. Depending which loop is activated, a state's capacity to deal with future stress is either damaged, neutralized, or enhanced and subsequently results in the state being categorized as fragile, robust or antifragile.

The experimental design which is developed in much more detail in the next chapter focuses on running the model through two world types. World A focuses on providing insights into how antifragility is important for state survival. To explore this, the state variables, percent-learn and percent-forget, were set to a value of 0 so that states remain forever in their antifragility capacity category (either fragile, resilient, or antifragile), and the model was run over several iterations with other varying parameters as described in Chapters 4 and 5. World B focuses on providing insights into what kind of world is best for state survival and maintaining antifragility. In this experimental world, the percent-learn and percent-forget variables were not set to a value of 0. Again, the model was run over several iterations with varying parameters. In both worlds, metrics such as length of life, portion of time spent being antifragile, and final performance values were measured and analyzed in understand how the state variables influenced the outcomes of these independent variables.

VERIFICATION AND VALIDATION OF THE MODEL

This section reviews the literature on model verification and validation and lays out an appropriate plan for validation of the dissertation model in Chapter 4 using approaches suggested by and justified in the literature. The verification and validation plan for the dissertation model is implemented in Chapter 4 and as such discussed in greater detail in the next chapter.

As with any modeling and simulation undertaking, the process of verification and validation is a critical one. As Osman Balci writes in his piece, *Golden Rules of Verification, Validation, Testing, and Certification of Modeling and Simulation Applications*, "verification, validation, and testing (VVT) are not a state or step in the M&S development life cycle, but a continuous activity throughout the entire life cycle."[106] The detection and correction of errors as early as possible is preferable in that it reduces development time and assures better quality.

Verification suggests that the computational model should be consistent with the specification model. In other words, verification answers the question, did we build the model right? According to Banks and Sokolowski (2009), typical questions to be answered during the verification process include:

- Does the program code of the executable model correctly implement the conceptual model?
- Does the conceptual model satisfy the intended uses of the model?
- Does the executable model produce results when it is needed and in the required format(s)?[107] (Banks & Sokolowski, p. 126)

[106] Whitner, Richard B., and Osman Balci. "1989 Winter Simulation Conference." In *Guidelines for Selecting and Using Simulation Model Verification Techniques*, 559–68. Washington, D.C.: IEEE Computer Society, 1989.
[107] Sokolowski, John A., and Catherine M. Banks, eds. *Principles of Modeling and Simulation: A Multidisciplinary Approach*. Hoboken, NJ: Wiley, 2009.

Validation, on the other hand, suggests that the computational model should be consistent with the system being analyzed. In other words, validation seeks to answer the question, did we build the right model?[108] Again according to Banks and Sokolowski (2009), typical questions to be answered during validation include:

- Is the conceptual model a correct representation of the simuland?
- How close are the results produced by the executable model to the behavior of the simuland?
- Under what range of inputs are the model's results credible and useful?[109] (Banks & Sokolowski, p. 126)

While the verification and validation process occur at various points throughout the modeling process, this dissertation highlights verification and validation at three points throughout the model development life cycle: conceptual model, computerized model, and operational model development phases. A more detailed discussion of the verification and validation techniques applied at each of the three-model development life cycle phases is discussed later in the sections that focus on the verification and validation plans.

There are numerous possible verification and validation techniques to choose from. Table 5 provides an abbreviated list of verification and validation techniques published by the Defense Modeling and Simulation Office (DMS) in their Recommended Practices Guide.

[108]Cook, David A., and James M. Skinner. "Systems & Software Technology Conference." In *How to Perform Credible Verification, Validation, and Accreditation for Modeling and Simulation*, 2005.
[109] Sokolowski, John A., and Catherine M. Banks, eds. *Principles of Modeling and Simulation: A Multidisciplinary Approach*. Hoboken, NJ: Wiley, 2009.

Table 5: Abbreviated Verification and Validation Techniques According to the Defense Modeling and Simulation Office's Recommended Practices Guide[110]

Informal	Static	Dynamic	Formal
Audit Desk Checking Face Validation Inspections Walkthroughs	Cause-Effect Graphing Control Analysis Assessment	Acceptance Testing Alpha Testing Assertion Checking Fault/Failure Insertion Testing Field Testing Sensitivity Analysis Visualization/Animation	Induction Inference Logical Deduction Proof of Correctness

What is important to take away from Table 5 are the four main types of verification and validation that differ in terms of their structure, guidelines, and cost. By understanding the characteristics of each, an informed decision on which types of verification and validation are best for the model in this dissertation can be made. For regardless which category the verification and validation technique fall into, it is critical to remember that of the numerous techniques described in Table 5 the modeler should always determine which technique is most appropriate for their particular project.

Starting from the right-hand side of Table 5, formal analysis is based upon formal mathematical proof of corrections.[111] As Sargent writes, "If attainable, formal proof of correctness is the most effective means of verifying software. Unfortunately, "if attainable" is the overriding point with regard to formal analysis."[112] This technique brings with it a high level of formality, complexity, and effectiveness; however, it is human resource intensive. Due to these reasons, formal analysis was determined to not be the best fit for this dissertation.

[110] "Verification, Validation & Accreditation, VV&A- The Key Concepts." Defense Modeling and Simulation Enterprise, October 27, 2020. https://vva.msco.mil/.
[111] Whitner, Richard B., and Osman Balci. "1989 Winter Simulation Conference." In *Guidelines for Selecting and Using Simulation Model Verification Techniques,* 559–68. Washington, D.C.: IEEE Computer Society, 1989.
[112] Richard Whitner and Osman Balci, Guidelines for Selecting and Using Simulation Model Verification Techniques.

Dynamic analysis is defined as analyzing results gather during the model execution. As the model is exercised, its behavior is observed and information about its execution is gathered. The technique brings with it a moderate to high level of complexity, human resources, and effectiveness. This instrument-based technique also has a higher computer resource cost and can range between informal levels of complexity to formal levels of complexity.

Static analysis is defined as analyzing characteristics of the static source code. That is static analysis does not require execution of the model. The effectiveness and computer resource cost of this technique is considered moderate to high, with a moderate level of complexity. The human resource cost for this technique falls in the informal to formal range.

Finally informal analysis is defined as analyzing through the employment of informal design and development activities. This technique employs a low level of complexity, computer resource cost, and is considered very high in the human resource cost. For the purpose of this dissertation a mixed technique approach of informal, static, and dynamic verification and validation techniques were chosen. Table 6 summaries a plan for the verification and validation techniques and types with a discussion on what each technique consists of justification for its use, and the plan for execution. Further details on how the execution of the verification and validation process was specifically completed is provided in Chapter 4.

Table 6: Summarization of the Verification and Validation Plan

Modeling Stage	**Analysis Technique**	**Type**
Conceptual	Informal	**Verification:** walkthrough
	Informal	**Validation:** face validation and traces
Computerized	Informal	**Verification:** testing and debugging

Table 6: Continued

Modeling Stage	**Analysis Technique**	**Type**
Computerized	Informal and Dynamic	**Validation:** NetLogo's code check feature and dynamic testing
Operational	Static and Dynamic	**Verification:** syntax analysis, testing, and debugging
	Informal	**Validation:** face validation, case studies

Conceptual Verification and Validation Plan

The verification techniques chosen for the conceptual modeling stage are those that come from informal category, specifically walkthrough.[113] Walkthroughs are the most time-consuming and most formal of the informal methods. For the purpose of this dissertation, Dr. Richman was identified as the secondary person to conduct desk checking, and me as the primary. Having Dr. Richman serve as the secondary and not the primary person to conduct a walkthrough was done to enhance the completeness and reliability because as Whitner and Balci (1989) write, "the modeler often becomes blinded by his own mistakes."[114]

The validation technique chosen for this dissertation are those from the informal and dynamic analysis categories (Table 6). The first place identified for validation is identified at the during the conceptual model phase. According to Sargent, "conceptual model validation is defined as determining that the theories and assumptions underlying the conceptual model are correct and that the model representation of the problem entity is 'reasonable' for the intended purpose of the model." The primary validation techniques used for the conceptual model

[113] While a walkthrough is typically carried out by a team of individuals associated with the development process, the concept of a walkthrough was modified for the purpose of this project so something smaller and less formal.
[114] Richard Whitner and Osman Balci, Guidelines For Selecting and Using Simulation Model Verification Techniques.

validation included face validation and traces. For the purpose of face validation, subject matter experts were identified at the beginning of the conceptual modeling phase of the dissertation to ensure that both the variables captured in the model were valid and the behavior the model produced was consistent with their understanding of antifragility. First, Dr. Jesse Richman, the dissertation's advisor, was identified as one such subject matter expert. Additionally, Garth Jensen, the Director of Innovation at the Carderock Naval Surface Warfare Center, was identified as someone who could conduct face validation due to his expertise in antifragility and complexity thinking.

The use of traces is the tracking of entities through each sub model and the overall model to determine if the logic is correct and if the necessary accuracy is maintained. Again, Dr. Jesse Richman was identified as a subject model expert who could help ensure the validation of the model at this phase through his background and extensive experience in modeling and simulation.

Computerized Verification and Validation Plan

The process of testing reveals the presence of errors and debugging finds those errors and removes them. Specifically, debugging involves locating the source of the error, determining the needs for correcting the error, making the correction, and then retesting the model to ensure successful modification. Both testing and debugging are an inevitable step of the simulation model development life cycle.

Computerized model validation is defined as assuring that the computer programming and implementation of the conceptual model is correct." The primary techniques for validation in at this phase included dynamic testing, and use of NetLogo's internal code check feature, which highlights any syntax errors made during the course of programming the model. Dynamic testing was conducted whereby the computer program was executed under different conditions. From here, the values obtained were used to determine if the computer program and its implementations are correct. In other words, did the input produce an expected outcome or something completely different? This process proved especially important when validating the behavior of the different agent types (fragile, resilient, and antifragile) to ensure that each produced an outcome in accordance with their type.

Operational Verification and Validation Plan

According to Whitner and Balci, “any model that is to undergo translation from a higher form to a machine-readable form must first pass a syntax test.”[115] A syntax check assures that the mechanics of the language are being applied correctly and is one of the most widely used verification techniques. Notably, testing and debugging is a repetitive cycle during the model development life cycle and is therefore determined to be a necessary technique during the operational phase of the model development life cycle. My colleague, Dr. Erdem Karaköylü provided syntax checks once the model was complete. His current experience as a data scientist at Research Innovations Incorporated (RII) and former experience as a software engineer and data scientist at NASA Goddard Space Flight Center lent itself well to assuring the mechanics of the programming language were applied correctly. This process occurred over the course of two weeks whereby the model code was shared with Dr. Karaköylü for comments and then shared with me for corrections.

Finally, operational validation is defined as determining that the model’s output behavior has sufficient accuracy for the model’s intended applicability. Here, the simulation model behavior can be explored either quantitatively or qualitatively. Qualitatively, the directions of

[115] Richard Whitner and Osman Balci, Guidelines For Selecting and Using Simulation Model Verification Techniques.

the output behaviors were examined along with an internal check on the magnitudes to ensure they were reasonable. The primary validation technique chosen for this project is that of face validation. Face validation involves asking individuals knowledgeable about the system whether the model and/or its behavior are reasonable. In this case, observers may be potential users or subject matter experts with respect to the simuland review or observe the results of the simulation. According to Banks and Sokolowski, "based on their knowledge of the simuland, the observers subjectively compare the behavior of the simuland as reflected in the simulation results with their knowledge of the behavior of the actual simuland under the same conditions, and judge whether the former is acceptably accurate."[116]

For the purpose of face validation, two subject matter experts were identified- Dr. Jesse Richman and Dr. Matthew Largent. Dr. Largent was selected as his primary role at the Naval Information Warfare Center Atlantic as a Mission Engineer includes modeling and simulation. Additionally, subject matter expert of antifragility and intimate familiarly with the work of Nassim Taleb.

DISADVANTAGES AND ADVANTAGES OF INFORMAL VERIFICATION

One of the primary disadvantages of informal verification strategies is that they are more qualitative than quantitative and generally rely heavily on subject human evaluation rather than detailed mathematical analysis. Since this model is the first of its kind and theoretical, it is preferable to have more of a qualitative than quantitative method of verification for several reasons. First the literary influences on this model (Taleb and Treverton, 2015 and Johnson and Gheorghe 2012) come from two different fields of study, international studies and engineering. Taleb and Treverton (2015) do not provide any quantitative measures or methods by which to

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[116] Sokolowski, John A., and Catherine M. Banks, eds. *Principles of Modeling and Simulation: A Multidisciplinary Approach*. Hoboken, NJ: Wiley, 2009.

understand state antifragility, and Johnson and Gheorghe (2012) give us an overview, but no details as to how to recreate their model. Therefore, a decision was made that the main priority of this model was to ensure that the behavioral aspects and outcomes of antifragility were accurately captured and modeled and laying a foundation for more quantitative versions and evaluations of the model to be produced in future research endeavors.

The value in choosing these techniques is that that they evaluate the subjective and multifaceted aspects of the simulation study. Allowing for human reasoning, rather than relying solely on computational correctness, ensures the acceptance of many subjective aspects of the model. As a theoretical model informed by interdisciplinary subject material, this advantage is important in order to allow for the expansion of this model into other disciplines and new directions.

THE USE OF CASE STUDIES FOR OPERATIONAL VALIDATION

Rather than trying to simply justify approaches other computational social sciences have already done, it is important to understand the way other social scientists consider validation. One such way is the use of case studies for validation. As Ahrweiler and Gilbert write, “validating a simulation against empirical data is not about comparing "the real world" and the simulation output; it is comparing *what you observe as the real world* with what you observe as the output. Both are constructions of an observer and his/her views concerning relevant agents and their attributes. Constructing reality and constructing simulation are just two ways of an observer seeing the world.”[117] Others who have utilized this technique include Sallans, Pfister, Karatzoglou, and Dorffner in their 2003 paper, *Simulation and Validation of an Integrated Markets Model in the Journal* of Artificial Societies and Social Simulation (JASSS).

[117] Ahrweiler, Petra, and Nigel Gilbert. “Caffè Nero: the Evolution of Social Simulation.” *Journal of Artificial Societies and Social Simulation* 8, no. 4 (October 31, 2005). https://doi.org/https://www.jasss.org/8/4/14.html.

As a result, two case studies are presented in Chapter 6 and Chapter 7 that provide evidence to suggests the model correctly captured the real-world dynamics of state antifragility. A deeper discussion of this evidence is examined in Chapter 6 and Chapter 7.

As Deffuant, Moss, and Jager write, "validation against case studies can also take the form of having independent experts or observers assess the qualitative behaviour of agents. By their nature, of course, agent based social simulation models of case studies support validation against history."[118] Furthermore, there is precedence for this using case studies within the process of validation as exemplified by Sallans, Pfister, Karatzoglou, and Dorffner (2003) and Bobbie, Schreckenberg, Dyke, Schaafsma, and Balbi (2016). [119][120]

RESEARCH METHOD OVERVIEW

This research will apply and evaluate a simulation modeling approach to understand why some states are more antifragile than others and why antifragility matters. This study design will use a mixed methods approaches to achieve its objectives. First, research into the existing scholarly literature on state fragility and resilience is conducted to inform the intuitions about the characteristics of state antifragility and fragile/antifragile state behavior. Next, those intuitions are developed, tested, and validated into an agent-based simulation model of state antifragility. Both qualitative and quantitative methods will be used to evaluate the simulation model as a theoretically based model of state antifragility. Two case studies are used to validate that the model correctly captured the real- world dynamics of state antifragility.

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[118] Deffuant, Guillaume, Scott Moss, and Wander Jager. "Dialogues Concerning a (Possibly) New Science." *Journal of Artificial Societies and Social Simulation* 9, no. 1 (January 31, 2006). https://www.jasss.org/9/1/1.html.
[119] Sallans, Brian, Alexander Pfister, Alexandros Karatzoglou, and Georg Dorffner. "Simulation and Validation of Integrated Markets Model." *Journal of Artificial Societies and Social Simulation* 6, no. 4 (October 31, 2003). https://doi.org/https://www.jasss.org/6/4/2.html.
[120] Doobie, Samantha, Kate Schreckenberg, James G. Dyke, Jarije Schaafsma, and Stefano Balbi. "Agent-Based Modelling to Assess Community Food Security and Sustainable Livelihoods." *Journal of Artificial Societies and Social Simulation* 21, no. 1 (January 31, 2018). https://doi.org/10.18564/jasss.3639.

CONCLUSION

In conclusion, this chapter provides justification for the use of modeling and simulation as the best method to explore state antifragility. Specifically, agent-based modeling, was determined to be best technique suited to address the problem statement of this dissertation due to its holistic, bottom-up approach. In addition to the benefits and advantages outlined in the first half of this chapter, disadvantages to undertaking modeling and simulation were identified and discussed, along with ways in which these challenges are being addressed in order to provide a well-rounded view of the modeling and simulation process.

Next, a high-level overview of the model presented in Chapter 4 was included in this chapter as a means to introduce the readers to the detailed and often technical discussion of the model found in the following chapter. Finally, the chapter concludes with a section on the importance of verification and validation in the modeling and simulation life cycle, with a focus on outlining the verification and validation process for this particular project through informal means.

THE MODEL

Overall, the purpose of this chapter is to provide the reader with both the logic and technical expression of the model. One of the keys to help ensure a successful simulation is a well-organized model process. Specifically, this chapter presents the model development in an organized manner, moving from conceptual model to model implementation as a computational model, and finally to model validation and verification, and a plan for experiments using the model.

In this chapter, the model is presented in at three levels- conceptual, specification, and computational, moving from very high level to an Overview Design concepts, and Details (ODD) protocol found in the Appendix. The conceptual model provides the reader with a very high-level overview of the model and includes the problem formulation and objectives. Additionally, it focuses on defining the state variables and understanding which are dynamic and important. Next, the specification level provides the reader with both equations and the pseudocode of the model and addresses how the model will receive input. Finally, the most detailed level of the model is that of the computational level. To present this, I use the ODD protocol, used for describing individual-and Agent-Based Models (ABMs) to provide a consistent, logical, and readable account of the structure and dynamics of ABMs (Grimm, et.al., 2019)[121].

To further aid the readers, the chapter format mirrors that of Banks, Carson, Nelson, and Nicol's Steps in Simulation Study graph.[122] The basic steps and decisions for simulation include the following: problem definition, project planning, system definition, model formulation, input

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[121] Grimm, Volker, Gary Polhill, and Julia Touza. "Documenting Social Science Simulation Models: The ODD Protocol as a Standard." Essay. In *Simulating Social Complexity*, 117–33. London, UK: Springer, 2013.
[122] Carson, John S., Jerry Banks, Barry L. Nelson, and David M. Nicol. *Discrete-Event System Simulation*. New York, NY: Pearson, 2010.

data collection and analysis, model translation, verification and validation, experimentation and analysis, and documentation and implementation. The first portion of this chapter focuses on the problem definition and system definition, model formulation and input data collection and analysis.[123] Since the focus of this project is academic in nature, and not one based on contractual obligations, this step is omitted from the workflow of this chapter.

The second half of this chapter focuses on the various ways in which experiments of the model were constructed is discussed in the experimental design section of this Chapter, with two experiments conducted in total. Overall, the main difference between each of the experiments focuses on varying the amount of learning and forgetfulness a state has organizationally into two world types. That is, in the first word the states do not forget the level of antifragility capacity they have and do not learn new antifragility capacity, and in the second world states do possess the ability to learn and forget antifragility capacity. In addition to the differences in the learning and forgetfulness variables, each world type is designed to answer a different question that relates back to the original research question of the dissertation, *what makes some states more antifragile than others and why does this matter*? In the world with the learning and forgetfulness variables are set to a value 0 (World A), the experimental structure is designed to answer the question, *why is antifragility important for state survival*? In the world where the learning and forgetfulness variables take on values greater than 0 (World B), the experimental structure is designed to answer the question, *what kind of world is best for maintaining antifragility*? The question in World A provides support to answering the second part of the overall dissertation research question, *why does this (antifragility) matter,* by fixing the state type

[123] For the purpose of this chapter, project planning is omitted. Project planning focuses on breaking down the tasks into work packages, and individuals are then assigned to each work page. The project milestones are also indicated for tracking progress, and a schedule is created to determine if sufficient time and resources are available for completion

to understand how an antifragile state performs across key variables relative to resilient and fragile state types. The question in World B provides support to answering the first part of the overall dissertation research question, *what makes some states more antifragile than others,* by understanding under what circumstances antifragility emerges and is maintained. Finally, the limitations of the model are discussed at the end of this chapter.

PROBLEM FORMULATION

Prior to constructing a model, it is important to be clear about the nature of the problem under consideration and the project objectives. As Banks writes, "problem formulation involves defining the goals of the study and determining what needs to be solved, with the problem further defined through objective observations of the process to be studied."[124] As Chapter 1 discussed, antifragility suggests that some states are benefiting from stressors and shocks, while others are degrading as a result of these same stressors and shocks. To better understand why this happens, it was useful to consider the literature on antifragility, state resiliency, and state fragility. The decision problem/decision objective is to create an agent-based model of state antifragility in order to understand the difference different levels of state antifragility and fragility make for state performance and survival.

With this intention, there is a need to identify what needs to be understood in order to begin to address the problem decision/problem objective. Based on the literature review in Chapter 2 and the methodology discussed in Chapter 3, it is important to understand the following:

A. The defining characteristics of antifragile states,

B. The important attributes of stress,

[124] Banks, Jerry, ed. *Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice*. New York, NY: John Wiley & Sons, Inc., 1998.

C. How to quantify and model both A and B, and

D. The process by which states interact with stress to produce outcomes of fragility, resilience, and antifragility for states.

Each of these is discussed in greater detail in the next sections.

OBJECTIVES

The second step is to identify the objectives of the simulation study. That is, the objectives indicate the questions that are to be answered by the simulation study. Generally speaking, the objectives for this project include:

1. Increasing understanding of the state characteristics that produce fragile, resilient, and antifragile outcomes,
2. Increasing understanding of the process by which these same state characteristics produce fragile, resilient, and antifragile outcomes,
3. Studying how and in what ways antifragility influences state performance and state survival, and
4. Identify real world examples (case studies) of state antifragility.

To increase the understanding of state characteristics that produce fragile, resilient, and antifragile outcomes, a robust review of the literature pertaining to state fragility in Chapter 2 was presented. The two primary sources of interest for this objective are that of Taleb and Treverton (2015) and Johnson and Gheorghe (2012). Taleb and Treverton (2015) provide readers with five characteristics of state fragility/antifragility in their Foreign Affairs article, *The Calm Before the Storm*. Johnson and Gheorghe (2012) present a system level overview of how an antifragile system is constructed in their piece, *Antifragility Analysis and Measurement Framework for Systems of Systems*. Furthermore, this work also proposes a series of criteria that can aid in improving a system's ability to survive a threat. These criteria include entropy, emergency, efficiency vs. risk, balancing constraints vs. freedom, coupling, requisite variety, stress starvation, redundancy, non-monotonicity, and absorption. These works provide a basis for answering the question, *what makes states antifragile*?

Within the wider field of global politics, understanding state antifragility and the characteristics thereof potentially helps explain how some states fare better than others given the same set of conditions? To quote Taleb and Treverton, "how has seemingly stable Syria turned out to be the fragile regime, whereas always-in-turmoil Lebanon has so far proved robust?"[125] Having a greater understanding of these characteristics in the context of state antifragility, may help provide answers to questions such as the one posed by Taleb and Treverton.

Additionally, understanding state antifragility could allow for International Relations scholars and practitioners to anticipate who the "winners", "losers", and "sleeper states" in the next major global shock might be. This in turn has implications for how we think about power-politics, political world order, and security. For example, if some states benefit from (or believe they benefit from) experiencing shocks, could their perceived aggressive behavior be now viewed as an opportunity to increase learning and become antifragile? Are the governance and security structures some states have implemented inadvertently inhibiting their ability to become antifragile? Given this previous question, understanding state antifragility could provide a blueprint for creating, organizing and structuring state/international institutions (i.e., adapt them to be more antifragile).

Analysis of how and in what ways antifragility influences state performance and state survival provides a new and unique basis for assessing, interpreting, and understanding events in

[125] Taleb, Nassim Nicholas, and Gregory F. Treverton. "The Calm Before the Storm: Why Volatility Signals Stability, and Vice Versa." Foreign Affairs, 2015. https://www.foreignaffairs.com/articles/africa/calm-storm.

international relations. For example, if antifragility increases a state's performance and enhances its chances of survival, then it can be presumed beneficial for states to experience stress or volatility. Perhaps, states may even begin to seek out stress or volatility for in order to reap the benefits. The use of agent-based modeling to study these characteristics and processes allows for the explicit concretizing of these variables and relationships such that others can modify and change parameters to explore alternate assumptions concerning antifragile state behavior and the environment in which states act. Certainly, these variables will evolve over time and through other's interpretations and refinements. Furthermore, the subsequent use of case studies also provides us with the means to understand what difference antifragility makes as they allow us to understand the real-world implications of this influence. One of the most salient examples of this is in Chapter 6 which examines how the United States military was caught flatfooted against a much less capable adversary by traditional measures of military power. As the case study and model demonstrate, learning, power conversion, and agility all play a role in the way in which an emergent adversary impacted the United States' ability to perform in the War on Terror for a period of time.

SYSTEM DEFINITION

The system definition step involves identifying the system components to be modeled and the performance measures to be analyzed.[126] The system components show the key concepts of an explanatory theory and the hypothesized relationships between them. Key concepts can be characterized as variables, or any entity that can take on different values. The values variables can take are then specified and it is made clear which are included in the study.

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[126] Banks, Jerry, ed. *Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice*. New York, NY: John Wiley & Sons, Inc., 1998.

Key Concepts of State Antifragility

Four key concepts of antifragility emerged from the literature in Chapter 2 that influenced the conceptual and computerized model. These key concepts are summarized in Table 7 and are followed by a discussion of those concepts. Emanating from these key concepts are the specific variables, found in Table 8 that were modeled in the conceptual model and computerized model.

Table 7: Key Concepts of State Antifragility

Concepts	**Informed by…**
1. States are the primary agents and are endowed with a certain set of characteristics that make for more or less fragility, robustness, or antifragility.	Taleb and Treverton (2015) Johnson and Gheorghe (2012)
2. Stress is present in the environment and varies depending on how chaotic the environment is.	Taleb and Treverton (2015), Johnson and Gheorghe (2012)
3. States interact with stress in the environment and stress has some effect on the state.	Taleb and Treverton (2015), Johnson and Gheorghe (2012)
4. As a result of state-shock interaction, the response of a state to a shock will fall into one of three categories-fragile gets weaker, resilient returns to status quo, and antifragile gets better.	Taleb and Treverton (2015), Johnson and Gheorghe (2012)

CONCEPTUAL MODEL FORMULATION

Understanding how the actual system behaves and determining the basic requirements of the model are necessary in developing the right model. To do so, a series of tables is presented in the following sections that marry the key concepts from Table 7 to the model variables. Additionally, the understanding how these variables interact is important and discussed in greater detail in the subsequent section.

The first key concept that emerged from the literature is that states are the primary actors. As such, one of the most pivotal aspects of this model is the state and its characteristics that influence state antifragility. Recall from Chapter 2, the Foreign Affairs article, *The Calm Before the Storm*, by Nassim Taleb and Gregory Treverton that describes five characteristics of state fragility/antifragility. These characteristics were transposed to three original propensity variables-agility, power conversion, and learning, as described in that chapter. However, these three propensity variables underwent an additional transformation to the final characteristics of the state that are captured in the final model (Table 8).

In the final model, the propensity variable agility is expressed through a state's recovery time and recovery magnitude. That is the amount of time it takes a state to recover from a shock and the extent to which a state recovers from a shock, respectively. The propensity variable power conversion is conveyed through the state's performance, the ability of a state to absorb stress without dying, and its antifragility capacity. The remaining propensity variable, learning, is captured in the state's ability to learn or forget from its previous experiences, and by its antifragility capacity. Table 8. summarizes the model variables for key concept #1 in Table 7.

Table 8: Model Variables for Key Concept #1

Key Concept #1: States are the primary agents and are endowed with a certain set of characteristics (variables).

Original Variables	**Propensity Variables**	**Final Model Variables**	**Definition of Final Model Variable**
1. Concentrated Decision Making *2. Political Variability*	Agility	Recovery Time	The amount of time it takes the state to recover from a shock.
		Recovery Magnitude	The extent to which the state recovers.

Table 8: Continued

Original Variables	**Propensity Variables**	**Final Model Variables**	**Definition of Final Model Variable**
1. Economic Diversity *2. Debt to Leverage Ratio*	Power Conversion	Performance	The ability of a state to absorb stress without dying.
		Capacity	The defining characteristic of a state's type-fragile, resilient, or antifragile.
1. History of surviving past shocks	Learning	Learning	The ability of the state to learn from its previous experiences and its capacity.
		Forgetfulness	The forgetfulness of the state of its previous experiences.

The second key concept of antifragility that is captured in the model contends that stress must be present in the simulation environment and vary depending on how chaotic the environment is (Table 9). Codified in the model as a shock, stress is defined as anything that disrupts a state's performance and may impact the state's antifragility capacity (Table 9).

There are two important characteristics of stress that must be accounted for in the model (Table 10). First, how chaotic or stressful the environment is for a state is determined by the number of stressors present in the environment. The fewer number of shocks in the environment, the less chaotic the environment can be perceived to be. The greater the number of shocks in the environment, the more chaotic the environment can be perceived to be. It is also important to note that stress is genericized in the final model. That is, specific types of stressors are not identified by type (i.e., natural disaster, coup, etc.). This level of distinction should be left for future iterations of the model whereby the impact of a specific type of stressor may hold implication for how the state variables are affected differently, but for the purpose of this dissertation stress is nonspecific.

Table 9: Model Variables for Key Concept #2

Key Concept #2*: Stress must be present in the environment.*

Key Concept	**Defined by…**	**Final Model Variable**	**Definition of Final Model Variable**
Stress	Not defined in the literature.	shocks	Anything that disrupts a state's performance and may impact the state's capacity. Shocks possess different intensity values. Finally, shocks may be very frequent or infrequent depending on how chaotic the environment is.

The second important characteristic of stress is the intensity of those stressors or shocks. The intensity of a stressor is indicative of the severity of the stress, given that stressors may vary from small scale (i.e., death of a state leader) to large scale (i.e., war to include a nuclear exchange).

The third key concept that emerged from the literature is states interact with stress in the environment and stress has some effect on the state (Table 11). One of the key notions of antifragility is having a history of surviving past shocks, something International Relations scholars and practitioners presently view as indicative of instability. Through the lens of antifragility, this history can be viewed as opportunities for the state to learn from their experiences. Furthermore, their survival of this "virtue of volatility" as Taleb and Treverton (2015) refer to it, signals that states such as Indonesia, Malaysia, the Philippines, South Korea, and Thailand were robust enough to survive the 1997-1998 Asian financial crisis for example, but their "impressive subsequent performance suggests that they might even have been antifragile, adjusting to their institutions and practices based on lessons of the crisis."[127] Similarly, China's intense experience with the SARS outbreak may have contributed to its success as one of the only countries to successfully contain the COVID-19 pandemic through public health measures prior to the development of a vaccine.

Table 10: Stress Characteristics, Final Model Variables, and Values

Stress	**Stress- Final Model Variables**	**Definitions**
Number of Shocks	Shocks	Indicative of how chaotic the environment is for a state. The more shocks present in the environment, the more chaotic the environment is perceived to be. The fewer shocks present in the environment, the less chaotic the environment is perceived to be.
Mean	Number-mean	Value used in the ɑ equation to determine the Gamma distribution's skewedness. Also used in the ƛ parameter to determine the scale of the Gamma distribution.
Variance	Number-variance	Value used in the ɑ equation to determine the Gamma distribution's skewedness. Also used in the ƛ parameter to determine the scale of the Gamma distribution.

Subsequently, what is most important about this interaction is the effect the stress has on states. To cite Taleb and Treverton (2015) again, "the idea is analogous to child rearing: parents want to protect their children from truly serious shocks that they might not survive but should not want to shelter them from the challenges in life that make them tougher."[128] From this quote, two things can be ascertained. First, the intensity of the stressor has implications for the effect it

[127] Taleb and Treverton, The Calm Before The Storm: Why Volatility Signals Stability and Vice Versa, Foreign Affiars, 2015, p. 93.
[128] Taleb, Nassim Nicholas, and Gregory F. Treverton. "The Calm Before the Storm: Why Volatility Signals Stability, and Vice Versa." Foreign Affairs, 2015. https://www.foreignaffairs.com/articles/africa/calm-storm.

has on the state. That is to say, full scale nuclear war (high intensity) will almost without a doubt bring the most antifragile state to its end; however, experiencing moderate armed conflicts might in fact strengthen states by developing veteran forces with sharpened skills and experiences.

Second, the frequency with which states experience stress is critical to the stress' effect on the state. One intense stressor may have the same effect on a state as a clustered series of less intense stressors, particularly as it pertains to a state's recovery efforts. For example, Puerto Rico is exposed to tropical cyclones throughout the Atlantic hurricane season; however, the effects of the 2017 hurricane season were widespread and catastrophic for this archipelago. In September 2017, Hurricane Irma, a category 5 storm, passed close to the main island of Puerto Rico on September 7, causing substantial power outages and water service interruptions. Less than two weeks later, Puerto Rico was hit yet again by a category 4 hurricane named Maria on September 20. As the most intense hurricane to make landfall in Puerto Rico since 1928, the quick succession Hurricane Maria immediately after Hurricane Irma interrupted the ongoing recovery operations of Puerto Rico from the first hurricane. As a RAND report, *Hurricanes Irma and Maria: Impact and the Aftermath*, says, "the one-two punch of Hurricanes Irma and Maria, combined with the economic challenges and other stressors that Puerto Rico was facing prior to these storms, led to an extended disaster response period."[129] The example of the impact two successive hurricanes had on Puerto Rico illuminates the importance of the frequency of stress.

[129] "Hurricanes Irma and Maria: Impact and Aftermath." RAND. Accessed 2021. https://www.rand.org/hsrd/hsoac/projects/puerto-rico-recovery/hurricanes-irma-and-maria.html.

Table 11: Model Variables for Key Concept #3

Key Concept #3*: States interact with stress in the environment and stress has some effect on the state.*

Observation	**Effect on the State**
1. Stress and states interact with stress.	A state's ability to recover and perform in the future is impacted by the state's interaction with stress.
2. Stress intensity has an effect on the state.	If a stress is too intense, it can cause a state to die, regardless of whether they are fragile, resilient, or antifragile.
3. The frequency of stressors, regardless of their intensity, have an effect on the state.	The more frequent the stressors interact with the state, the greater the negative effect on the state if the state does not have time to recover between stressors.

The final key concept is the categorization of the three state types that occurs as a result of the stress-state interaction. The three state types are fragile, resilient, and antifragile. In the model, each is determined by the state's capacity variable, which is in turn related to how well the state recovers after experiencing stress. Table 12 summaries how these three state types are determined.

If a state's stress-coping or antifragility capacity is too small, then after experiencing stress, the state's ability to perform is reduced immediately and recovery during the state's recovery period is too small to recover to the previous status quo. This type of state is considered fragile. Antifragile states are discerned by their high capacity, such that after experiencing stress, the state's ability to perform is reduced immediately, but during the recovery period the state recovers to a level better than the original level known prior to experiencing the stress. Finally, the resilient state is one who's capacity falls somewhere in-between the fragile and antifragile state. It's ability to perform is reduced immediately after experiencing a shock, too; however, the resilient state recovers to the level previously known prior experiencing the shock or stress. What is it, though, that enables the antifragile state to benefit from experiencing stress and others to experience detrimental consequences?

Table 12: Model Variables for Key Concept #4

Key Concept #4: *As a result of state-shock interaction, the state will fall into one of three categories based upon its capacity to handle stress-fragile, resilient, and antifragile.*

State Type	**If Condition**	**Then Behavior**
Fragile	If a state's capacity is too small, then…	After experiencing stress, a state's performance is reduced immediately and recovery during the recovery period is too small to recover to the previous status quo level of performance.
Resilient	If the state's capacity falls somewhere in between fragile and antifragile, then…	After experiencing a stress, a state's performance is reduced immediately and recovers during the recovery period to the level previously known prior to experiencing the stress.
Antifragile	If a state's capacity is large enough, then…	After experiencing stress, a state performance is reduced immediately but the state recovers to a level of performance better than the original level known prior to experiencing the stress.

In addition to recovery and antifragility capacity, it is also about learning and forgetting. How well a state learns during its period of recovery is expressed through the additional two propensity variables, power conversion and agility. If a state exhibits a high level of learning (low level of forgetfulness), it can be surmised that the state will be better able to sense, respond, adjust, and adapt their strategies, as a function of their changing circumstances. Recall from Chapter 2 that the process by which states become agile is one in which states make small changes quickly, adapt to those changes, and most importantly learn from those changes. On the other hand, high levels of forgetfulness undermine the very definition of agility in that they are unable to learn from their adjusted strategies and produce favorable outcome.

Similarly, learning plays an integral part in power conversion, or resources and strategy used in combination to induce a desired behavioral outcome of a state. When a high amount of learning is present (low level of forgetfulness), then states are better able to leverage their agility to adapt their strategies and better utilize their resources. Conversely, when a high level of forgetfulness is present in a state, then the result might be a lack of strategy, as evidenced by the initially botched counterinsurgency after the invasion of Iraq by the United States in 2003 discussed in Chapter 6.

Hypothesized Relationships of State Antifragility Variables

Now that the key concepts have been captured, it is important to discuss the variables and relationships through which these key concepts emerge in the model. Recall from Chapter 3 the Overview of the Model Process figure, Figure 3. This figure outlines the three major occurrences within the model and the behaviors and outcomes of each occurrence. Each of these three major occurrences is presented in a series of tables and discussed in greater detail below.

In order to answer the central research question, *why are some states more antifragile than others*, the agent-based model focuses on the performance and life of a single state moving through an environment that contains shocks of various magnitudes. The key characteristic of the state is whether it possesses antifragility, which impacts the extent to which the state is able to get better, stay the same, or get worse after encountering a shock. Table 13 outlines what transpires prior to the state hitting a shock in the environment.

Table 13: Prior to Hitting a Shock

Behavior	**Variable**
1. State maintains performance at same value.	s = state performance c = state antifragility capacity f = state forgetting parameter

Table: 13 Continued

Behavior	**Variable**
2. Depending on the magnitude of the forgetting parameter, state antifragility decreases, and the state may transition its type.	The magnitude of the forgetting parameter shapes how quickly a state may lose antifragility capacity during a period of calm when has not encountered and is not recovering from a shock. States that forget rapidly will tend to move rapidly from antifragile to resilient, and ultimately from resilient to fragile.

States begin with a level of performance (s) and an antifragility capacity variable (c) which (depending upon which thresholds for the variable they cross) leads the state to be classified as fragile, antifragile, or resilient. Until a state hits a shock, the state will maintain the same performance value (s). However, as the literature on antifragility reviewed above emphasizes, lack of experience with shocks can render a state more fragile. Hence over time, and conditional upon the magnitude of the forgetting parameter (f), state antifragility capacity may degrade, with initially antifragile states potentially transitioning to resilient states, and ultimately to fragile states if no shocks are encountered for a prolonged period relative to the magnitude of the forgetting parameter.

When a state encounters a shock (h) in a time period (t), several things happen. First its performance is immediately degraded. Performance is reduced by shock magnitude ($S_t = S_{t-1} - h$), and if state performance drops below zero ($S_t \leq 0$), the state will die, and the simulation terminates (Table 14). Then the parameters for the recovery process are set. Recovery magnitude (m) is set, based on state fragility, resilience or antifragility and number of recovery periods (p). For an fragile state the total recovery experienced is less than the hit from the shock (total recovery over *p* periods = *mp* < h), for resilient states recovery will eventually return the state to its prior level (mp = h), and for antifragile states recovery will eventually lead to performance above the level initially possessed by the state (mp > h.)

Table 14: When the State Hits a Shock at Time (t)

Behavior	**Variable(s)/ Equation(s)**
1. State hits a shock of magnitude.	(h)
2. Performance is reduced by shock magnitude.	($S_t = S_{t-1}$ -h) ***note:** If the state performance drops below zero ($S_t \leq 0$), the state will die, and the simulation will terminate.
*3. Recovery magnitude (m) is set. (***note**: based on state fragility/resilience/antifragility and the number of recovery periods (p)).*	mp < h (fragile state)
	mp = h (resilient state)
	mp > h (antifragile state)
4. Depending on the magnitude of learning parameter (l), state antifragility capacity increase to the state may move from fragile to resilient to antifragile.	Capacity > (10) = antifragile
	Capacity ≤ (10) and capacity ≥ (4) = resilient
	Capacity < (4) = fragile
	l= learning parameter

Hitting a shock may also allow a state to develop its antifragility capacity, rendering it better able to deal with future shocks. Thus, the third major event when a state hits a shock involves learning, modeled as an increase in the antifragility capacity variable. Depending upon magnitude of the learning parameter (l), state antifragility capacity increases, potentially moving a fragile state up to a capacity level that renders it resilient, or a resilient state up to a level of capacity that means it will be antifragile if it encounters another shock before this capacity degrades.

After hitting a shock, the state enters the recovery period (Table 15). During each turn of the recovery period (p) state performance recovers by the recovery magnitude ($S_{t+1} = S_t + m$). At the conclusion of the recovery period, a fragile state will have recovered to a level of performance below its previous performance, a resilient state will have returned to its initial performance level, and an antifragile state will have recovered to a level of performance better than its initial performance. After the recovery period ends, a state will begin to once again forget antifragility capacity (conditioned by the magnitude of the forgetting parameter) until it once more encounters a shock.

Table 15: After the State Hits a Shock

Behavior	**Variable(s)/ Equation(s)**
1. After hitting a shock, the state enters the recovery period.	(p)
2. During each turn of the recovery period, state performance recovers by the recovery magnitude.	($S_{t+1} = S_t + m$)

The conclusion of the recovery period is dependent upon the type of state (Table 16). A fragile state will recover to a level of performance below its previous performance; a resilient state will return to its initial performance level. An antifragile state recovers to a level of performance better than its initial performance.

Table 16: At the Conclusion of the Recovery Period

Behavior	**Outcome**
1. The conclusion of the recovery period is dependent upon the type of state-fragile, resilient, or antifragile.	A fragile state recovers to a level of performance below its previous performance.
	A resilient state returns to its initial performance level.
	An antifragile state recovers to a level of performance better than its initial performance.

As Table 17 shows, there are two conditions under which the simulation will terminate. First, if state performance drops below zero, then the state can no longer perform, and it "dies." The death of a state triggers one condition for simulation termination. The second condition is one of time. As described in Chapter 5, some states will "break away" and continue to be antifragile forever until some imposed condition. As a result, when the simulation reaches 2000 ticks, the other condition for simulation termination is met.

Table 17: Conditions Under which the Simulation Terminates

Condition	**Outcome**
1. State performance drops below zero ($S_t \leq 0$).	The state will "die", and the simulation terminates.
2. The simulation reaches 2000 ticks.	The simulation terminates.

Data

With a general understanding of occurs during the model, it is important to discuss the nature of the model at this point and the subsequent choices for data values.

This model is a theoretical one whose purpose is to capture the characteristics and process by which states become fragile, resilient, or antifragile over time, and the consequences of state fragility or antifragility for state performance and state survival. In the case of finding data to inform this model, I quickly determined that trying to map the final model variables in Table 4 by aggregating variables from real-world indices such as the FSI and OECD Index was too great of a challenge for this dissertation and best left for future research. Instead, a concerted effort was placed on understanding what the variable impacts relative to the broader behavior of the model. As G. Wunsch points out in his article *Theories, models and data,* "models are an intermediate between theory and data. Data are used to confirm or falsify theories and models…however, data do not impose themselves upon the scientist, other forms of scientific explanation exist, and some theories of models may have no link with data."[130]

Conceptual Model Verification and Validation

Recall from Chapter 3, that the verification and validation process is one that occurs throughout the modeling life cycle. The verification technique chosen for both the conceptual model and computational model is that of a series of iterative walkthroughs, conducted by Dr. Jesse Richman and me.

A walkthrough was conducted with every substantive change to the model. The walkthroughs were conducted both synchronously and asynchronously depending on the phase of the model development. For the synchronous meetings, Dr. Richman and I shared the code via Zoom, and examined the code line by line, procedure by procedure. The model was run under various parameter spaces to ensure the desired behavior outcome was achieved based on the changes instantiated. Once the code was updated then run, a consistency check was

[130] Wunsch, G. "Theories, Models, and Data." *Demografie* 36, no. 1 (1994): 20–29. https://pubmed.ncbi.nlm.nih.gov/12346076/.

conducted, again by me and Dr. Richman, to ensure the encoded behavior was consistent with the principles of antifragility. In the case of minor changes such as variable ranges, asynchronous walkthroughs were conducted whereby the model was sent to Dr. Richman via email for comments and then sent back to me.

As a result of these iterative walkthroughs a number of changes emerged. For example, earlier versions of the model included variations on the number of states present in the world, as well as how these states propensity variables were determined. In the first iteration of the model, the number of states included in the model were three. Each state began with a different type, that is one was endowed with properties to categorize it as fragile, and other endowed with properties to categorize it as resilient, and the third state endowed with properties to categorize it as antifragile; however, it was quickly determined that only the behavior of one state needed to be analyzed for the purpose of this model, as anything else was considered superfluous in order to determine if antifragility was modeled correctly. Additionally, real world data from the Fragile States Index was collected and regression analysis used in order to understand the mathematical relationship among the three propensity variables; however, using this data provided further abstractions upon abstractions that moved the model further away from its simple design. Thus, the data from the Fragile States Index was removed to allow for exploration of a wide range of theoretically relevant conditions.

Furthermore, walkthroughs revealed an obvious omission in one of the earlier versions of the model. Most notably missing in earlier versions of the model was the idea of recovery of a state in the environment. Previous versions of the model did not account for the recovery period of a state after it experiences a shock, black boxing the entire process and making it instant. How a state recovers after experiencing a shock is, at the core, what differentiates a fragile state from a resilient state from an antifragile state. Therefore, the addition of a "to recover" function was included in the model's code and its final version, allowing for study of the impact of various length recovery periods on state performance and state survival.

Over the course of model development several adjustments were made to the code in order to address any errors that appeared when executing the model. Errors included order of operations, range consistency for state type, and other errors that were easily identifiable and corrected.

To validate the conceptual model the technique of face validation and traces were used. For the purpose of face validation, subject matter experts were consulted over the course of this dissertation to ensure that both the variables capture in the model were valid and the behavior the model produced was consistent with their understanding of antifragility. First, Dr. Jesse Richman, the dissertation's advisor, was consulted throughout the entirety of the project. Second, Garth Jensen, the Director of Innovation at the Carderock Naval Surface Warfare Center, was consulted for his expertise in antifragility and complexity thinking. As someone I have worked with for over ten years, his knowledge and expertise on antifragility is one that precedes even the conception of this project.

Meetings with Mr. Jensen occurred early on as the conceptual model was being developed and during the application of the case studies to the model. The conceptual phase model meetings consisted of phone conversations discussing what the literature has to say about antifragile behavior, and then roughly translating that literature to a processes overview of how an antifragile, resilient, and/or fragile entity should behave.

Mr. Jensen was also integral in the face validation of the case studies in Chapter 6 and Chapter 7, as the Iraq War (2003-2011) and the rise of China are two areas in which he specializes. Examining the historical narrative and ensuring its accuracy for both case studies was also validated by Dr. Nicholas Law, who has first-hand experience as a United States Marine from 2001 to present day and authored a dissertation examining the franchising effects of Al Qaeda in 2016. Additionally, his current assignment in the Marine Corps focuses on the Indo-Pacific and the great power competition with China.

Dr. Richman and I conduced the tracking of entities through each sub model and the overall model to determine if the logic was correct and if the necessary accuracy was maintained. During these tracking sessions, it was determined that some of the initial model logic did not make sense. For example, a resilient agent would sometimes behave as a fragile agent or vice versa. It was determined that some of the capacity ranges that determined the agent type were not inclusive of certain values and were therefore producing behavior inconsistent with the agent type. These issues were identified and corrected as they were discovered.

A section below in this chapter on operational verification and validation (after the presentation of the computational model) continues the discussion of verification and validation through the examination of a series of model runs. The discussion of validation then continues through the case study chapters (6 and 7) below.

MODEL TRANSLATION

At this stage, the model is now ready to be translated into a programming language. The model presented in this chapter advances and aims to build an agent-based model that combines the ideas of Taleb and Treverton's Foreign Affairs article with the system dynamics model of Johnson and Gheorghe (2013). This study seeks to understand the theoretical underpinnings of antifragility as it applies to states in the international environment. As such, this goal necessitates the use of modeling and simulation to provide that theoretical exploration.

There are three primary components of an agent-based simulation- agents, environments, and time. For the purpose of the reader's orientation into the model, the next portion of this chapter is partitioned into three sections that address the environment, the agent, and the interaction between the two.

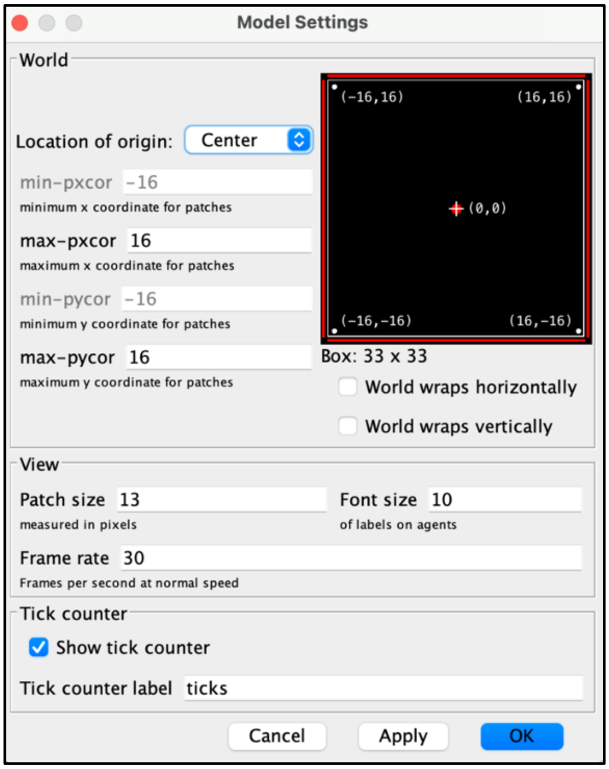
The Environment

The environment is the space in which the agents exist. Environments can be as abstract as an empty space or as realistic as a representation using layers of geographic information. The environment in this model is an abstracted representation of the international environment in which states live. Physically, the world is represented by a 33x33 box whose maximum x coordinate for patches is 16 and maximum y coordinate for patches is 16. The location of the origin of this world is centered at (0,0), and each individual patch size is 13 pixels (Figure 4).

The inspiration and influence for the construction of the environment is that of the 1960's classic approach to visualizing states in International Relations, the billiard ball model.[131] In this state-centric approach, associated with the realist theory, states are like billiard balls that are impermeable and self-contained, which influence each other through external pressure. An empty table represents the global level of analysis and within that table are individual billiard balls which represent the state level of analysis. The model visualizes international relations as states bouncing around an international environment and crashing into other things, as a result of military and security matters. States are basically the same. They react to exogenous forces and come into conflict with one another according to how the system or table is set up and how outside forces put states in one direction or another.[132]

[131] Wolfers, Arnold. *Discord and Collaboration: Essays on International Politics*. Baltimore, MD: The Johns Hopkins Press, 1962.
[132] Wolfers, Arnold. *Discord and Collaboration: Essays on International Politics*.

Figure 4: Model Settings



For the purpose of this model, shocks are represented by patches. There are two types of patches within the environment, red and black. The first type of patch is denoted by the color black and has no interactive effect with the state. The second type of patch represents shocks in the environment and is denoted by the color red. These patches possess an intensity value, and thus have an interactive effect with the agent discussed in the subsequent sections of this chapter.

There are two important characteristics of the shocks in this model. First, the number of shocks in the environment is determined by the slider variable *number-shocks*. This variable ranges from 0 to 200 in the experiments described below and may be changed in increments of 1. The greater the number of shocks in the environment, the more chaotic the environment can be perceived to be. The fewer number of shocks in the environment, the less chaotic the environment can be perceived to be, but equally important to the number of shocks in the environment is the intensity of those shocks.

The intensity value of a shock is indicative of the severity of the shock, given that shocks may vary from small scale to large scale. In order to determine the intensity of the shocks, the shocks were pulled from a Gamma distribution. While a variety of useful probability distributions could have been used to determine the intensity value of the shocks, the Gamma distribution was used because it is a continuous distribution that allows for its parameters to be defined on the base of their physical or geometric interpretation, as well as, being one of three basic types, location, scale or shape parameters.[133] The scale and shape parameters of a gamma distribution are particularly useful for thinking about shock intensity in the real world as shocks vary based on their scale (intensity or light) and their shape, or duration of time the shock lasts (short or long) among other characteristics. That is, the severity and the frequency of the shock matters when modeling antifragility.

Within the gamma distribution, the α (alpha) and ƛ (lambda) parameters respectively influence the scale and shape of the gamma distribution that the intensity of the shock is drawn from. In other words, the α parameter is considered the shape parameter of the gamma distribution. A change in α generally alters a distribution's properties (e.g., skewness). In this model, the α parameter is determined by the following equation:

α = ((gamma-mean*gamma-mean)/ gamma-variance))

Additionally, the ƛ parameter is considered the scale parameter of the gamma distribution. That is, a change in ƛ compresses or expands the associated distribution without altering its basic form. In this model, the ƛ parameter is determined by the following equation:

[133] Law, Averill M. *Simulation Modeling & Analysis*. New York City, New York: McGraw hill Higher Education, 2006.

$$\lambda = (1/\ (\text{gamma-variance}/\text{gamma-mean}))$$

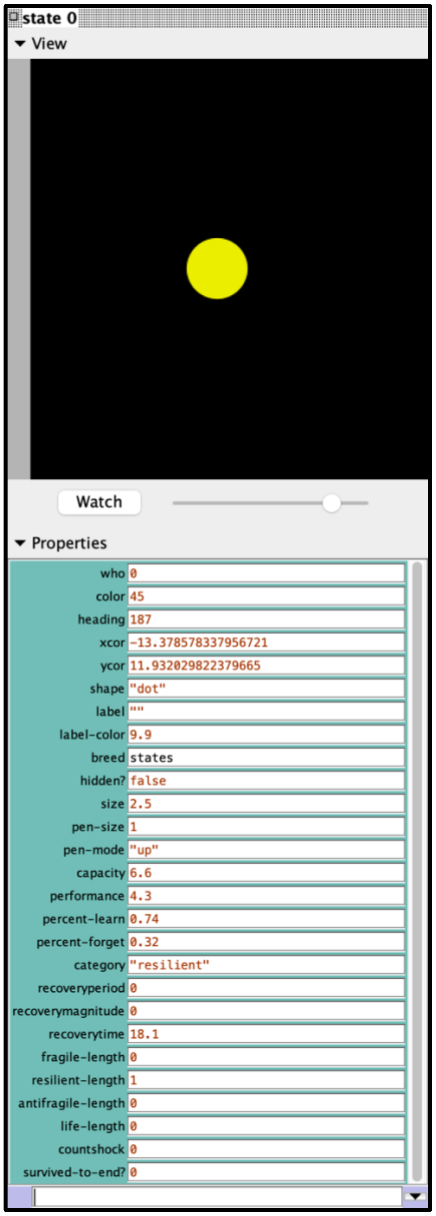
As one of the defining characteristics of each world type in each experimental run, the shock intensity was determined by predetermining the gamma mean and gamma variance, which then in turn, determined the α (shape) and λ (scale) of the gamma distribution from which the intensity value was determined. For the purpose of this model, the mean is determined by the variable *number-mean* which can take any value that ranges from (0, 10) and changes in increments of 1. The variance value is determined by the variable *number-variance* which can take any value that ranges from (0, 10) and changes in increments of 1.

It is important to note that the environment is an abstraction of reality. Shocks in the environment do not disappear after the state has encountered them, nor do they lessen in intensity, or change physical locations after the state has encountered a shock. Earlier versions of the model had the shock disappear after the state encountered it; however, this had the effect of diminishing the probability of hitting a shock over time, which is unrealistic. Though the design choice of keeping a shock in place after the state encounters it implies that the state has a higher chance of encountering a shock after encountering the first one, it does have several advantages. First, this keeps the model as simple as possible. Second, this design choice allows for greater complexity and fidelity to be added to the model in subsequent extensions of the model. For example, in future iterations as the propensity variables are further defined different shocks might impact different aspects of a state differently. Additionally, the introduction of more states into the model allows for interaction between states, not just between shocks (patches) and states.

The Agent

Recall from Chapter 2 that agents are endowed with certain characteristics that range from having a goal, existing within the environment, communication, and movement. The agent in this model represents a single nation-state and is represented in the environment by the NetLogo shape, dot. The agent is endowed with the following characteristics: *capacity*, *performance*, *percent-learn*, *percent-forget*, *category, recoveryperiod*, *recoverymagnitude, recoverytime*, *fragile-length*, *resilient-length, antifragile-length*, and *life-length* (Figure 5).

Figure 5: Individual Agent and Its Properties



Each of the characteristics interact with one another to produce a variety of behaviors within the simulation. To explain the variables requires an understanding of the context in which the variables are used in the model. The subsequent section below provides greater detail into these interactions. However, prior to exploring the interaction between the agent and the environment an understanding of how the variables are initialized during the set-up of the simulation is imperative.

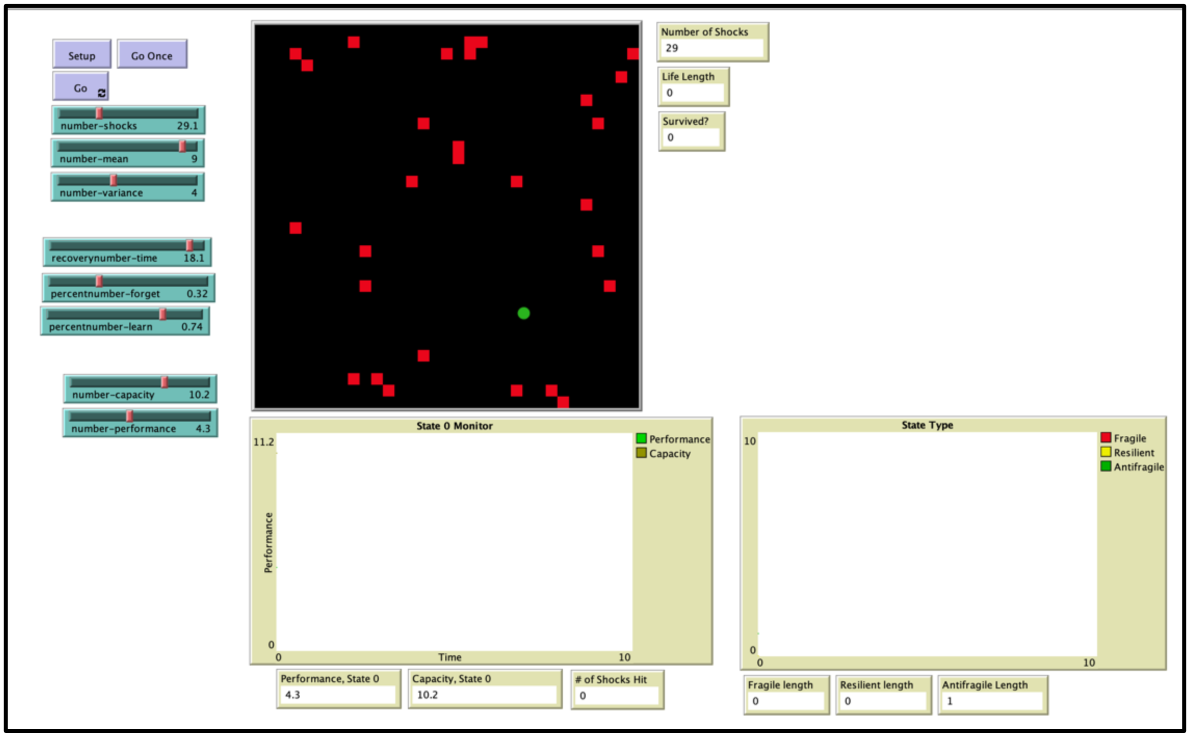
To set up the simulation, two main procedures, *grow-shocks* and *grow-states* are called. This next portion of the chapter will focus on the *grow-states* procedure as it pertains to the values of certain variables of the agent, namely, *capacity*, *percent-learn*, *percent-forget*, *recoverytime*, *performance*, *recoveryperiod*, and the *update-state-type* procedure.

The capacity variable is a slider variable called *number-capacity* and is found in the Interface Tab. The capacity value of the agent ranges from (0, 15), changes in 0.1 increments, and is determined by the user at the start of the simulation. *Number-capacity* plays a significant role in the simulation in two critical ways. First, it sets the ranges for determining the state type in the *update-state-type procedure*. In the model, the value of a state's capacity corresponds with certain values and colors, denoting the categorization of the agent (Table 18 and Figure 6). Second, it sets the ranges for determining how the state initially updates its performance value through the variable *recoverymagitude* within the same *update-state-performance* procedure.

Table 18: Capacity Values of the Agent

Capacity Value	**Agent Color**	**Agent Type**
c >= 10	green	antifragile
c >4 and c <10	yellow	resilient
c <=4	red	fragile

Figure 6: Antifragile Agent with Capacity >=10



The other attributes important to the state include the state's *performance*, *capacity*, *recovery*, and *recoverymagnitude*. It is important to discuss them in a particular order. Central to this discussion is the *recoveryperiod* variable that determines how rapidly a state recovers after encountering a shock. Upon set up of the simulation, the *recoveryperiod* value is initially set to 0, but later changes. Recovery time is important to the agent because it connects directly to the degree to which the state behaves in an antifragile way through the state's performance and more specifically agility. The sooner a state can recovery from a shock the more agile it is to respond to future shocks; the longer a state takes to recovery the less able it is to respond to future shocks.

In the model, the state's performance is a global variable whose range varies from a minimum value of 0 to whatever theoretical maximum the user determines. The value can be changed using the slider *number-performance* in increments of 1 in the Interface Tab. In the model, the variable performance appears twice in two main procedures, *update-state-performance* and *activate-loop*. Within the *update-state-performance* function, *recoverymagnitude*, *intensity* of the shock, *recoverytime*, *recoverymagnitude,* and *recoveryperiod* all interact. In order to update the state's performance, the capacity of the state must fall into one of three ranges. Depending on where the capacity value of the state falls at the time it meets a shock will determine how the state recovers through the *recoverymagnitude* variable. There are three possible outcomes for recovery. First, the state will recover to level of performance 20% better than its original performance value by the end of the recovery period if it is antifragile (capacity > 10). Second, the state will recover to the same original performance value it possessed prior to running into the shock if it is resilient (10 > capacity > 4). Finally, the state will deteriorate and does not recover or gain from encountering the shock if it is fragile (capacity > 4), with recovery returning the state to a level of performance 20% worse than performance prior to encountering the shock. Furthermore, the *recoverymagnitude* variable is defined by the interaction among the shock's intensity, the state's present *recoverymagnitude* at the time the state encounters the shock and the *recoveryperiod* variable. The new state performance is then calculated by subtracting the intensity of the shock from the state's performance (Table 19).

Table 19: Code for the Update-State-Performance Procedure in the Model

If Condition	Then Condition	Then Condition Calculation
c >= 10	set *m*	(*h* *1.2 / *recoverytime*) + (*m***p*) / recoverytime
c >= 4 and c < 10	set *m*	(*h* / *recoverytime*) + (*m***p*)) / recoverytime)
If c < 4	set *m*	((*h**0.8 / recoverytime) + (*m* **p*)) / recoverytime

Finally, the new state performance is then calculated by subtracting the intensity of the shock from the state's performance, and the *recoveryperiod* is updated to equal the *recoverytime*.

The proceeding function is the *activate-loop* procedure whereby the state's performance value updates the state's *capacity* value. Capacity is updated by adding the percent-learn value multiplied by the intensity of the shock to the capacity value. Table 20 below captures this relationship.

Table 20: Code for the Activate-Loop Procedure

If Condition	Then Condition	Then Condition Calculation
If s >= 0	set *c*	(*c* + (*l* **m*))

Interaction Between the State and The Environment

With the agent and the environment described in the previous two sections, the crux of this agent-based model is the interaction that occurs between the two. Interaction between the agent and the environment is executed via procedures in NetLogo. Within this model, there are twelve procedures. Table 21 summaries these procedures, and each is discussed in greater detail below.

Table 21: Procedures of the Model

Procedure Name	Definition
To Set Up	Begins defining a procedure named "set up." Within this procedure, the world is cleared, the sub-procedure "grow shocks" and "grow states" are called up on, the plots are set up and the ticks reset.

To Grow Shocks	Defines the shape, color, size, and intensity of the shocks in the environment. It determines how many shocks are present in the environment.
To Grow States	Defines the shape, color, size, and number of states created. Additionally, the state's characteristics of capacity, percent-learn, percent-forget, recoverytime, and performance are determined.
To Go	Moves the states throughout the environment, asks them to interact with shocks should they come across a red patch, update the plot, and die if the two die conditions are met.
To Move	Asks states to move randomly throughout the world. If a state does not encounter a shock, it's capacity variable declines.
To Interact with Shocks	Defines the interaction between states and red patches. If a state comes across a red patch, it calls up it the update state performance procedure, activate loop procedure and asks the counter to keep track of the number of shocks the state encounters.
To Update State Performance	Updates the state's performance after encountering a shock. First, the capacity of the state is updated based on its type-fragile resilient or antifragile. Next, the performance is updated based on the intensity of the shock. Finally, the recovery period is updated.
To Activate Loop	This procedure updates the state's antifragile capacity based on the performance being greater than 0.
To Recover	Recovery of the state is based on the state's performance and recovery magnitude. The recovery period is also updated here.
To Update State Type	Updates the state type based on some range of capacity values. Both the color and category are updated.
To Die	Determines the conditions for the termination of the simulation. If the state has a performance value less than 0, the simulation terminates. If the simulation reaches 2000 ticks, then it terminates.

At the beginning of every simulation is the set-up of the model. To set up the model run, first the world is cleared of any previous data, the commands "grow-shocks" and "grow-states" are called, the output plots are set up and ticks reset, which resets the tick counter to zero, sets up all plots, and then updates plots. Next, the model calls the two procedures, "grow-shocks" and "grow-states." The details of each of these commands was discussed in the previous two sections.

With the set up and initialization complete, the model is now ready to go. With the pressing of the "go" button, the model calls upon a series of procedures. The first is the "move-states" procedure which tells the states to move about the world randomly and bounce off the walls. Recall, earlier in the section on the agent, that states were endowed with eight characteristics-*capacity*, *performance*, *percent-learn*, *percent-forget*, *category*, *recoveryperiod*, *recoverymagnitude*, and recoverytime. Within the "move-states" procedure, capacity is set to the initial capacity value times 1- *percent-forget*. *Recoverymagnitude* is set to 0, and *recoveryperiod* is set to 0. Next, within this procedure is a conditional statement about the recovery period of the state, that states when the recovery period value of the agent is greater than 0, call the "recover" procedure. The recover procedure sets the performance of the agent to be equal to performance plus the recovery magnitude. Furthermore, the recovery period is set to the current value of the recovery period minus one, until it reaches a value of 0. Finally, the agent is categorized by a type in the model based upon the value of the capacity variable. The three types include fragile, resilient, and antifragile. As states move about their environment, regardless of whether or not they encounter a shock, their type will change based on the value of the agent's capacity to deal with future stress. If the capacity of the agent is greater than a value of 10, then the agent turns green indicating it is antifragile. If the capacity of the agent is less than a value of 10 and greater than or equal to a value of 4, then the agent turns yellow and is considered resilient. Finally, if the agent's capacity is less than 4, the agent turns red and is considered fragile.

As states move about their world, they will interact with their environment, through the *interact-with-shocks* procedure. This procedure conditions that when a state encounters a red patch, or shock, the agent will execute three additional procedures- the *update-state-performance* procedure, the *activate-loop* procedure, and the *countshocks* procedure. First, the state needs to update the state's performance. The state's performance is related to its capacity value. That is, the state's capacity to deal with future stress impacts its performance. Recall from earlier, there are conditions within this procedure that determine how the state recovers. First, if the state's capacity at the time it encounters a shock is greater than a value of 10, then the state will recover to by 20% greater than its original capacity value, indicating it is antifragile. If the state's capacity at the time it encounters a shock is less than a value of 10 but greater than a value of 4, then the state will recover to the same original capacity value it possessed prior to encountering the shock. Finally, if the state's capacity is less than a value of 4, then the state does not recover or gain from its interaction with the shock. Instead, it deteriorates by 20%, indicating it is fragile. Finally, the agent's performance will always take an initial hit from its interaction with the shock based on the value of the intensity of the shock. In addition to programming how the state recovers and performs, the recovery period of the agent is predetermined by the user and set within this procedure.

The next sub procedure within the *interact* procedure is the *activate a loop* procedure. This, too, is conditional upon the value of the agent's performance. That is if performance is greater than a value of 0, then learning, power conversion, and agility are all updated by multiplying the value of the intensity times 0.5 and adding resulting value to the current value of learning, power conversion, and agility. Additionally, capacity is subsequently updated at the end of the *activate-loop* procedure. Finally, the state keeps a count of the number of shocks it encounters over its lifecycle through the *countshocks* procedure.

Finally, the condition for the end of the simulation is set. This condition is solely based on the performance value of the agent, and in some runs (if the parameter is activated) upon an arbitrary end-of-simulation time at 2000 tics. If the agent's performance is less than or equal to 0, then it cannot function, and it dies. While this concludes the interactive portion of the model, there are reporters included in the model to provide values associated with certain variables. The variables with reporters include capacity and performance.

Operational Verification and Validation

Operational validation is defined as determining that the model's output behavior has sufficient accuracy for the models intended applicability. To do this the technique of face validity was conducted. Dr. Jesse Richman and I both conducted face validation of the model's outputs, whose results are captured in a series of figures below along with an accompanying discussion of each. Additionally, the process described below could also be considered as a form of sensitivity analysis in the sense that the runs demonstrate that the model parameters influence outcomes in expected ways.

To conduct face validity a series of runs for each state type was conducted to ensure that the correct behavior for each state type was captured, but that the correct output for each state type was realized. To do so various parameters were set up, consistent with each state type. The values of the percent-learn and percent-forget variables were set to 0 so that each state remained in its capacity category (antifragiles stayed antifragile, resilients stayed resilient, and fragiles stayed fragile). Figure 7, Figure 8, and Figure 9 capture these runs.

Figure 7. captures the output behavior to be expected from a fragile state in a relatively chaotic world (100 shocks). Prior to running the simulation, an inspection on the parameters was conducted. For the fragile state, we see a low capacity and low performance. Next, a visual inspection reveals that the state is characterized by the correct color (red). Finally, the output behavior seen in the State 0 Monitor graph within Figure 7 demonstrates how performance of the state after hitting a shock responds as expected. Specifically, the state recovers to a performance value lower than its preceding performance value. This run reveals that the state only hits two shocks before it dies, indicative of its fragility. Furthermore, the state has a short life length, 32 ticks. Overall, the fragile state behaves in accordance with the theoretical principles that inform it as well as the programming in the final code.

Figure 7: Example of Fragile Behavior

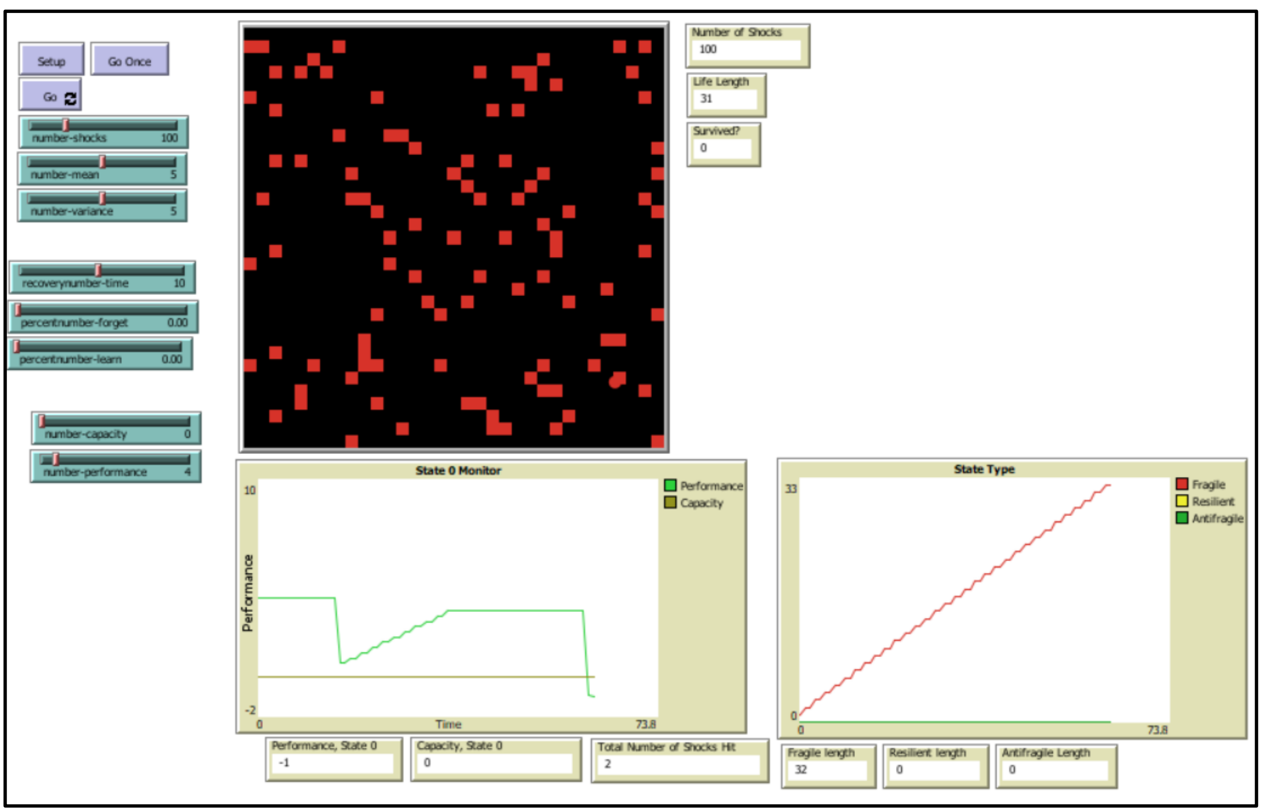


Figure 8 captures the output behavior to be expected from a robust state in a relatively chaotic world (100 shocks). Prior to running the simulation, an inspection on the parameters was conducted. For the resilient state, we see a medium capacity value (5) and medium performance values (6). Next, a visual inspection reveals that the state is characterized by the correct color (yellow). Finally, the output behavior seen in the State 0 Monitor graph within Figure 8 demonstrates how performance of the state after hitting a shock responds as expected. Specifically, the state recovers to a performance value lower than its preceding performance value. This run reveals that the state only hits four shocks before it dies, indicative of its medium capacity to become antifragile. Furthermore, the state demonstrates a longer life length than that of the fragile state, 59 ticks. Overall, the resilient state behaves in accordance with the theoretical principles that inform it as well as the programming in the final code.

Figure 8: Example of Resilient Behavior

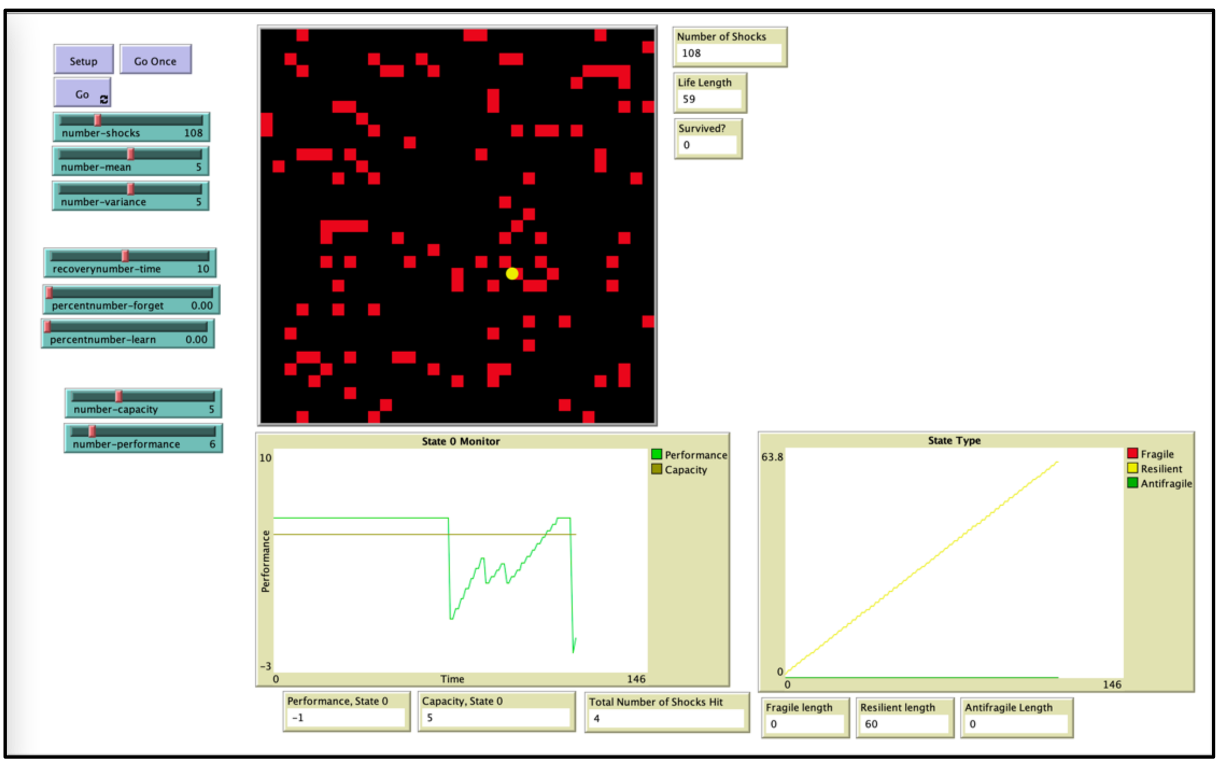
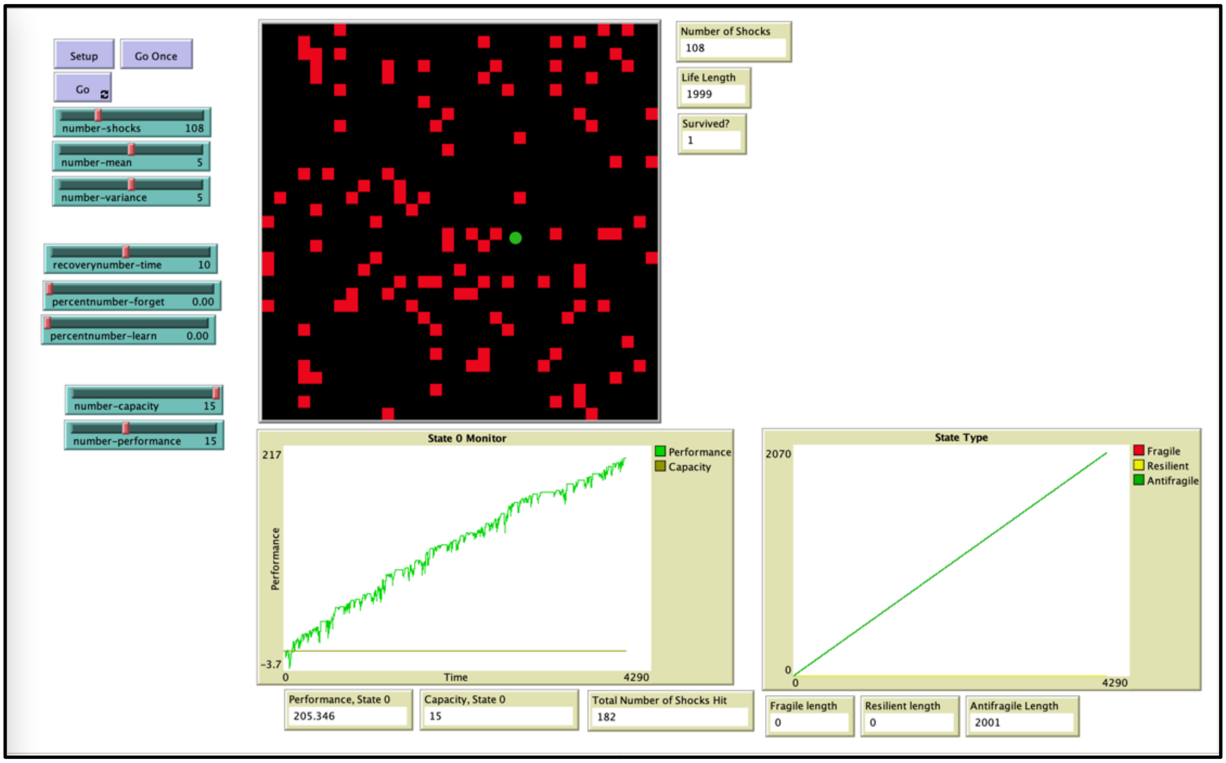


Figure 9 captures the output behavior to be expected from an antifragile state in a relatively chaotic world (100 shocks). Prior to running the simulation, an inspection on the parameters was conducted. For the resilient state, we see a high-capacity value (15) and high-performance value (15). Next, a visual inspection reveals that the state is characterized by the correct color (green). Finally, the output behavior seen in the State 0 Monitor graph within Figure 9 demonstrates how performance of the state after hitting a shock responds as expected. Specifically, the state recovers to a performance value better than its preceding performance value, and this allows for a pattern of increasing performance during the simulation, ultimately reaching a level of performance above 200. This run reveals that the state hits a high number of shocks, indicative of its high capacity to maintain antifragility. Furthermore, the state demonstrates a longer life length than that of the fragile and resilient states, it lived until the simulation automatically terminated. Overall, the antifragile state behaves in accordance with the theoretical principles that inform it as well as the programming in the final code.

Figure 9: Example of Antifragile Behavior



In addition to conducting verification and validation here, a second round of verification and validation is discussed in Chapter 6 and Chapter 7. I utilize the technique of face validity to examine the model and the validity of the model's assumptions in the case studies to determine whether the behavior of the model matches the behavior observed in the cases.

EXPERIMENTAL DESIGN

As mentioned at the beginning of the chapter, the experiments in this dissertation (which are analyzed in Chapter 5) were structured into two primary model types. The first model type is a static model in which capacity is fixed: states neither learn to be antifragile nor forget and cease to be antifragile. That is, their *percent-learn* and *percent-forget* variables are set to 0, and the state simply runs into shocks and remains fixed as either fragile, resilient, or antifragile. This model type is designated as the "World A." Recall from earlier that the experimental design in this world is designed to answer the question, *why is antifragility important for state survival*? The question in World A provides support to answering the second part of the overall dissertation research question, *why does this (antifragility) matter*, by providing fixing the state type to understand how an antifragile state performs across key variables relative to resilient and fragile state types.

The second world type is a dynamic model in which state capacity does change: they can 'learn' to have a higher capacity and become (more) antifragile, and they can forget their existing capacity and become (more) fragile. That is, the agent's *percent-learn* and *percent-forget* variables are greater than 0. This model type is designated as the "World B." In the world where the learning and forgetfulness variables take on values greater than 0 (World B), the experimental structure is designed to answer the question, *what kind of world is best for maintaining antifragility*? The question in World B provides support to answering the first part of the overall dissertation research question, *what makes some states more antifragile than others*, by understanding under what circumstances antifragility emerges and is maintained.

Static Capacity Model: World A Experimental Structure

The experimental design in World A is an 8 x 4 x 10 x 10 x 4 factorial design with 12800 unique combinations of variable values, involving multiple levels of the following variables: *number-shocks*, *number-variance*, *number-performance*, *recoverynumber-time*, and *number-capacity*. The total number of shocks present in the environment started at 25 and ended at 200 shocks at increments of 25. *Numbervariance* was varied across values of 1 to10 and change by increments of 3. *Number-performance* values were varied across values of 1 to 19 and change by increments of 2. *Recoverynumber-time* was varied across values of 1 to19 and change by increments of 2, and *number-capacity* was varied across values of 1 to 16, in increments of 5.

Consistent throughout the World A experiments are the two variables-*percent-learn* and *percent-forget* which are set to a value of 0 to represent that the agent does not learn nor forget its existing level of capacity during its lifetime. As discussed above, this means that states retain a constant level of capacity and thereby remain either fragile, resilient, or antifragile throughout the entirety of the simulation. This is done so that the results can be clearly and cleanly divided to examine the outcomes for states that are fragile, resilient, and antifragile. Additionally, the *gamma-mean* remains consistent across all of the experiments in this world with a value of 5. Since the critical aspect of the shocks is shock magnitude relative to state performance and state performance varies, it is not necessary to vary the mean.

While the mean shock stays the same, the extent to which shocks are clustered near the mean does vary. The variable *number-variance* begins at a value of 1 and increases by a value of 3 until it reaches a value of 10.

The extent to which states can survive an encounter with a shock is set by state performance. The variable *number-performance* begins at a value of 1 and increases by a value of 2 until it finally reaches a value of 19. Thus, some states begin their run with a performance level five times lower than the average shock, while others begin their run with a performance level four times greater than the average shock. The variable recovery-time beings at a value of 1 and increases by 2 until it reaches a value of 19, and the variable *number-capacity* begins at a value of 1 and increases by a value of 5 until it reaches a value of 16. This decision was made to ensure that each of the state types-fragile, resilient, and antifragile-were represented across a variety of recovery period and shock variances. The factorial design of the experiments is presented in the Table 23.

Table 22: World A: Hypothetical Factorial Experiment

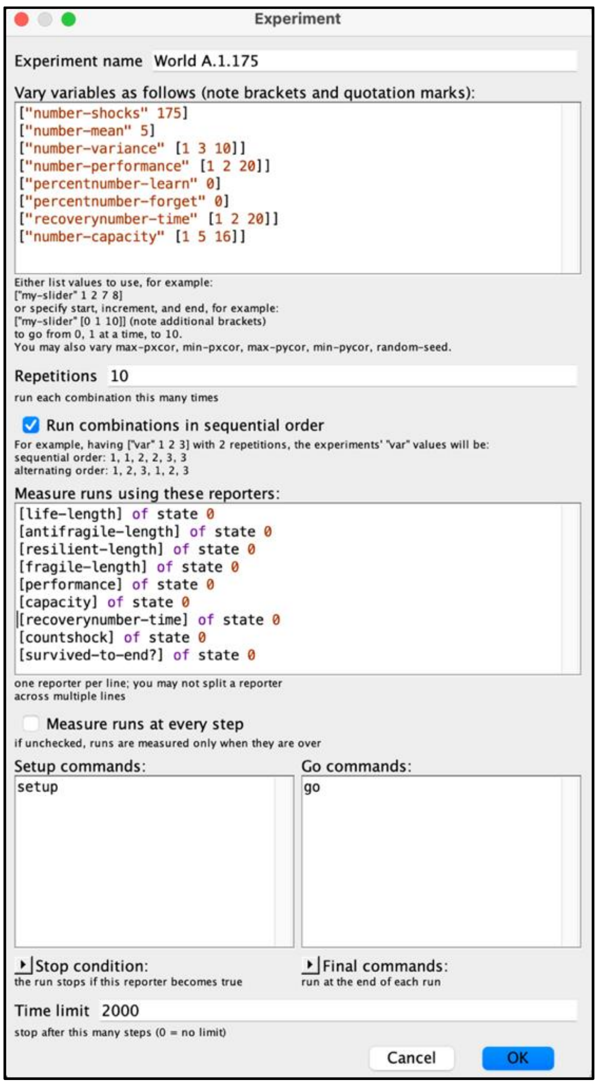
Components	**Values**
1. Number of Shocks	(25, 50, 75, 100, 125, 150, 175, 200)
2. Number-Variance	1, 4, 7, 10
3. Number-Performance	1, 3, 5, 7, 9, 11, 13, 15, 17, 19
4. Recoverynumber-Time	1, 3, 5, 7, 9, 11, 13, 15, 17, 19
5. Number-Capacity	1, 6, 11, 16
6. Percent-Learn	0
7. Percent-Forget	0

Table 23: World A: Experimental Conditions

Experimental Condition Number	**Number of Shocks**	**Number-Variance**	**Number-Performance**	**Recoverynumber-Time**	**Number-Capacity**	**Percent-Learn**	**Percent-Forget**
1	25	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	0	0
2	50	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	0	0
3	75	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	0	0
4	100	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	0	0
5	125	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	0	0
6	150	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	0	0
7	175	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	0	0
8	200	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	0	0

Each experiment measured the following dependent and tracking variables: life length of the agent, antifragile life length of the agent, resilient life length of the state, fragile life length of the agent, final performance of the agent, final capacity of the agent, final recovery time of the agent, the number of shocks the agent encountered during its lifetime, and finally whether the state survived to the end. Each combination of variable values was repeated 5 times with a time limit of 2000 steps.

Figure 10: World A: Experiment Structure in NetLogo



Dynamic Capacity Model: World B Experimental Structure

The experimental design in World B is an 8 x 4 x 10 x 10 x 4 x 10 x 10 factorial design with 1,280,000 unique combinations of variable values, involving multiple levels of the following variables: *number-shocks*, *number-variance, number-performance*, *recoverynumber-time*, *number-capacity, percent-learn, and percent-forget*. The total number of shocks present in the environment started at 25 and ended at 200 shocks at increments of 25. The variables *number-variance, number-performance*, *recoverynumber-time,* and *number-capacity* were all varied. *Numbervariance* was varied across values of 1 to10 in increments of 3. *Number-performance* values were varied across values of 1 to 19 in increments of 2. *Recoverynumber-time* was varied across values of 1 to 19 in increments of 2, and *number-capacity* was varied across values of 1 to 16, in increments of 5.

Consistent throughout these experiments is the *gamma-mean* variable which remains consistent across all of the experiments with a value of 5. As noted previously in the World A experimental structure, the critical aspect of the shocks is shock magnitude relative to state performance. Since state performance varies, it is not necessary to vary the mean.

The variable *number-variance* begins at a value of 1 and increases by a value of 3 until it reaches a value of 10 as in World A. The variable *number-performance* begins at a value of 1 and increases by a value of 2 until it finally reaches a value of 19, also as in World A. The variable recovery-time beings at a value of 1 and increases by 2 until it reaches a value of 20, and the variable *number-capacity* begins at a value of 1 and increases by a value of 5 until it reaches a value of 16. As in World A, this decision was made to ensure that each of the state types-fragile, resilient, and antifragile-were represented across a variety of recovery period and shock variances. Again, these variables are identical to those found in World A.

Table 24: World B: Hypothetical Factorial Experiment

Components	**Values**
1. Number of Shocks	(25, 50, 75, 100, 125, 150, 175, 200)
2. Number-Variance	1, 4, 7, 10
3. Number-Performance	1, 3, 5, 7, 9, 11, 13, 15, 17, 19
4. Recoverynumber-Time	1, 3, 5, 7, 9, 11, 13, 15, 17, 19
5. NumberCapacity	1, 6, 11, 16
6. Percent-Learn	0.01, 0.03, 0.05, 0.07, 0.09, 0.11, 0.13, 0.15, 0.17, 0.19
7. Percent-Forget	0.01, 0.03, 0.05, 0.07, 0.09, 0.11, 0.13, 0.15, 0.17, 0.19

Table 25: World B: Experimental Conditions

Experimental Condition Number	**Number of Shocks**	**Number-Variance**	**Number-Performance**	**Recoverynumber-Time**	**Number-Capacity**	**Percent-Learn**	**Percent-Forget**
1	25	(1, 10) incremental change of 3	(1,19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	(0.01, 0.2) incremental change of 0.02	(0.01, 0.2) incremental change of 0.02
2	50	(1, 10) incremental change of 3	(1,19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	(0.01, 0.2) incremental change of 0.02	(0.01, 0.2) incremental change of 0.02
3	75	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	(0.01, 0.2) incremental change of 0.02	(0.01, 0.2) incremental change of 0.02
4	100	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	(0.01, 0.2) incremental change of 0.02	(0.01, 0.2) incremental change of 0.02
5	125	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	(0.01, 0.2) incremental change of 0.02	(0.01, 0.2) incremental change of 0.02
6	150	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	(0.01, 0.2) incremental change of 0.02	(0.01, 0.2) incremental change of 0.02
7	175	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	(0.01, 0.2) incremental change of 0.02	(0.01, 0.2) incremental change of 0.02

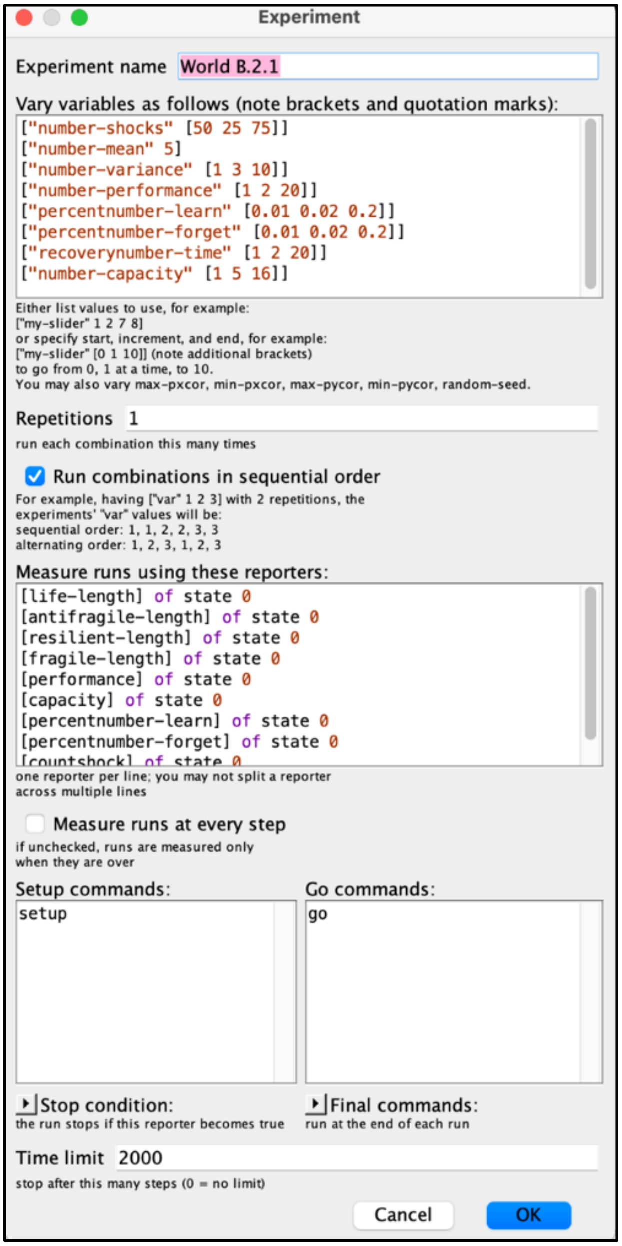
Table 25: Continued

Experimental Condition Number	Number of Shocks	Number-Variance	Number-Performance	Recoverynumber-Time	Number-Capacity	Percent-Learn	Percent-Forget
8	200	(1, 10) incremental change of 3	(1, 19) incremental change of 2	(1, 19) incremental change of 2	(1, 16) incremental change of 5	(0.01, 0.2) incremental change of 0.02	(0.01, 0.2) incremental change of 0.02

What differentiates World A from World B is in the *percent-learn* and *percent-forget* variables. Recall that *percent-learn* and *percent-forget* are set to 0 throughout each of the experiments within World A;however, within World B, *percent-learn* and *percent-forget* both begin at value of 0.01 and increase by 0.02 until it reaches value of 0.2.

As with World A, each experiment measured the following: life length of the agent, antifragile life length of the agent, resilient life length of the state, fragile life length of the agent, final performance of the agent, final capacity of the agent, final capacity of the agent, final percent-learn of the agent, final percent-learn of the agent, final recovery time of the agent, the number of shocks the agent encountered during its lifetime, and finally whether the state survived to the end. Finally, each of the 1,280,000 experiments was repeated 1 time with a time limit of 2000 steps (Figure 11).

Figure 11: World B Experiment Structure in NetLogo



Data Ranges for World A And World B

The data ranges chosen for World A and World B are mostly similar with one primary difference. That is in World B the percent-learn and percent-forget variables take on values other than 0. Specifically, *percent-learn* and *percent-forget* both begin at value of 0.01 and increase by 0.02 until it reaches value of 0.2.

Overall, it is important to remember that this is a theoretical model, and the variables are abstract theoretical constructs. The values of the ranges were determined because they covered an effectively wide range of values such that there are no interesting or important behavioral patterns were overlooked or missed because the experiment did not include the necessary parameter values.

MODEL ABSTRATCTIONS AND LIMITATIONS

Finally, as with any modeling endeavor, this model includes several abstractions and limitations. First, there is no specification of the various types of shocks in the world. From natural disasters to financial crises, to mass migration issues, wars, and global pandemics, a diverse set of shocks occur in the real world. Additionally, performance and capacity are the two primary variables impacted by the shocks. In the real system, each shock type would impact the state's propensity variables differently. In the real world, various types of shocks exist from economic shocks to natural disasters to name a few, and each tests components within a state differently. Economic shocks, for instance, typically do not require the state to call on the military to respond to or assist in recovery, although the military might be called on to address civil unrest. Natural disasters, on the other hand, may call on emergency management functions within the military and elsewhere.

Second, the process of becoming fragile, resilient, or antifragile is a slow and lengthy one requiring time. No real-world data was utilized in this theoretical model;however, this is discussed later in the chapter on future work. Since the use of real-world data is absent in this model and recommended for future use, it keeps the research at a theoretical level. Therefore, model runs can only be used to test and refine intuitions about antifragility such as those presented by Taleb and Treverton (2015) and Johnson and Gheorgie (2012).

Third, the interaction between states and shocks is random and unintentional. In the real-world states sometimes choose to engage in shocks or seek to avoid them, although the extent to which states can in fact avoid shocks is at best partial. Again, this focuses the research into a theoretical category by reducing some of the realism of the model, specifically as it relates to the agility variable, specifically agility in sensing. Intentional interaction requires foresight on the part of governmental leaders. This foresight ties directly to the ability of a person, system, or state to sense in an agile manner. In an international environment, states are intentionally interacting with both shocks and other states simultaneously. To do so successfully, agility must be present.

Fourth, states are modeled as unitary actors that do not have allies or belong to international organizations upon which they may call for aid in a time of crisis. In the real world, states may call upon allies and partners to provide support in the form of resources or in an effort to pursue mutual interests. Additionally, this decision regarding state behavior may hold implications for the performance variables, capacity variables, and learning variables. That is, states can increase their performance and capacity through inclusion in international organizations and may even increase opportunities for learning through shared norms.[134]

Next, one of the common difficulties of undertaking an agent-based modeling approach includes the integration of too many features and the choice of parameters. The results of the models are often criticized for being either trivial, or on the other hand, too complex. In the case of this model, the parameters for the variables were not informed by real world data, and stress was generalized, perhaps leading the model to be criticized as more trivial than complex. Since

[134] Barkin, Samuel. Introduction: The State and International Organizations, Retrieved From: https://link.springer.com/chapter/10.1057/9781403983237_1

this is the first agent-based model of state antifragility, the benefits of simplicity and generality were judged to outweigh the costs in potentially sacrificed specificity.

Another limitation in the model included the number of agents. While earlier versions of the model included more than one state present in the model and simulation, a decision to change the number of states to a single state occurred early on. First, limiting the number of states in the model to just one kept consistent with the unofficial "start simple and incrementally add complexity" mantra of those who undertake the modeling and simulation approach. This same rationale can be applied to why shocks were generalized and did not fall into specific types.

Second, keeping the number of state agents to one focuses the model to best address the central research question of the dissertation, *what makes states antifragile*? By keeping the focus on one state, the state characteristics of antifragility and the relationships of these variables front and center. States are as diverse as shocks, and the degree of fidelity present in this model is consistent with achieve its objectives.

Next, by using one state in the model, a variety of different contexts can be explored, particularly as they pertain to the distribution of shocks. That is to say, this design choice lends itself well to exploring state antifragility under different conditions, whereby shocks may be more or less frequent and more or less intense. While the distributions can be used to approximate interactions with another entity or state (as for instance the use of many small shocks to model the impact of many insurgent actions in Iraq in Chapter 6), this does limit the ability to use the model to directly explore strategic interactions between states. Instead, the model provides a foundation for future work which might seek to model such interactions in the context of (beliefs about) the antifragility of each state.

Finally, the last identified limitation resides in the verification and validation processes. The majority of the verification and validation techniques fell in the informal category and were conducted by subject matter experts close to the research project. In an ideal world, outside subject matter experts such as Dr. Gheorghe of the Johnson and Gheorghe (2012) antifragility paper could have been consulted to conduct the verification and validation of the model at various stages. Furthermore, social science modelers would have been consulted about whether validation of theoretical models is even meaningful.[135] However, given the time constraints and unforeseen challenges with the research project early on, these things did not occur. Finally, while informal verification and validation techniques are preferable to no verification and validation, the goal should always be to move towards a more formal approach. Furthermore, the face validity conducted in this research can be considered limited at best, as face validity is more than just comparing behavior to results.

CONCLUSION

This chapter provided the reader with both the logic and technical expression of the model. Overall, the model was presented at the conceptual, specification, and computational levels. The first half of the chapter presented the problem formulation and objectives of the model. Next the system definition, model formulation, and model translation were discussed in detail.

At the specification level, the model's equations and pseudocode were presented to the readers. Next, the technical and logical expression of the model is discussed in three parts. The first part focused on the model environment. The second part focused on the agent, and the third

[135] Anol Bhattacherjee, Social Science Research: Principles, Methods, and Practices, University of South Florida Scholar hattacherjee, Anol, "Social Science Research: Principles, Methods, and Practices" 2012). *Textbooks Collection*. 3. https://scholarcommons.usf.edu/oa_textbooks/3

part focused on the interaction between the agent and the environment. Throughout each of the three model life cycles (conceptual, computerized, and operational) verification and validation of each of these respective model life cycles is discussed.

The second half of this chapter focused on the various ways in which experiments of the model were constructed is discussed in the experimental design section of this chapter. Finally, the limitations of the model and methodology are presented to the reader for consideration.

MODEL RESULTS & ANALYSIS

The purpose of this chapter is to provide the model results from a series of experiments. The model results are presented into two different worlds, World A and World B. Each world and the subsequent series of experiments within those worlds is focused on addressing a series of questions that help scholars and practitioners understand what insights can be gained about antifragility. Additionally, analysis of those results is provided in a way that also illuminate the complexities of the world.

The static model analysis in World A focuses on providing insights into how antifragility is important for state survival. The first set of experiments examines the impact of antifragility, resiliency, and fragility on the life length of the agent (dependent variable) based on the following independent variables: initial performance (ability to absorb shocks without dying), recovery time, and the number of shocks in the environment. Recall from Chapter 4, each world type is designed to answer a different question that relates back to the original research question of the dissertation, *what makes some states more antifragile than others and why does this matter*? In World A, the experimental structure is designed to answer the question, *why is antifragility important for state survival*? This question provides support to answering the second part of the overall dissertation research question, *why does this (antifragility) matter*, by fixing the state type to understand how an antifragile state performs across key variables relative to resilient and fragile state types.

The second set of experiments examines the impact of antifragility, resiliency, and fragility on the final performance value of the agent (dependent variable) based on the following in dependent variables: initial performance (ability to absorb shocks without dying), recovery time, and the number of shocks in the environment. Recall that World A, a static model in which capacity is fixed: states neither learn to be antifragile nor forget and cease to be antifragile. That is, their *percent-learn* and *percent-forget* variables are set to 0, and the state simply runs into shocks and remains fixed as either fragile, resilient, or antifragile. In this world, the experimental structure is designed to answer the question, *what kind of world is best for maintaining antifragility*? This question provides support to answering the first part of the overall dissertation research question, *what makes some states more antifragile than others*, by understanding under what circumstances antifragility emerges and is maintained.

The dynamic model runs in World B examine what kind of world is going to be best for state survival and maintaining antifragility. The structure of the series of experiments is similar to that of world A but differs in one notable way. That is, we are now examining the impact of initial antifragility, initial resiliency and initial fragility on a series of dependent variables. In other words, states may begin the experiment as antifragile, resilient, or fragile but may end up in an entirely different category by the end of the experiment. Recall from Chapter 4 that in this world type, state capacity does change: states can 'learn' to have a higher capacity and become (more) antifragile, and they can forget their existing capacity and become (more) fragile. That is, the agent's *percent-learn* and *percent-forget* variables are greater than 0.

The first set of experiments examines the impact of initial antifragility, resiliency, and fragility on the life length of the agent (dependent variable) based on the following independent variables: initial performance (ability to absorb shocks without dying), recovery time, and the number of shocks in the environment, initial percent-learn value, and initial percent-forget value. The second set of experiments examines the impact of initial antifragility, resiliency, and fragility on the final performance value of the agent (dependent variable) based on the following in dependent variables: initial performance (ability to absorb shocks without dying), recovery time, and the number of shocks in the environment, initial percent-learn value, and initial percent-forget value. Finally, the last set of experiments inspects the impact of initial antifragility, resiliency, and fragility on the portion of time a state spends being antifragile (dependent variable) based on the following independent variables: initial performance (ability to absorb shocks without dying), recovery time, and the number of shocks in the environment, initial percent-learn value, and initial percent-forget value.

Overall, the structure of the experiments and the results of these experiments underscores the need for a simulation model to draw out how various factors in the model intersect and highlight different conditionalities, especially as it pertains to the ways in which states can 'learn' or 'forget' when it comes to their capacity to behave as antifragile states when confronted with shocks.

WORLD A RESULTS AND ANALYSIS

The main question for investigation for World A focuses on understanding how important antifragility is for state survival. The result from the experiments in World A is that antifragility is better; however, how much better is a result of *under what conditions* state experience stress.

Dependent Variable, Life Length

Figure 12 below examines the impact of antifragility, resilience, and fragility on a state's life length relative to the state's initial performance. Recall, that the state's initial performance is defined as the state's ability to absorb shocks without dying. The model runs reveal important non-linear interactions between the degree of state fragility/antifragility and the extent of state initial performance in shaping the average life length of the state.

Figure 12: Impact of Antifragility, Resilience, and Fragility on Life Length with Respect to Initial Performance (World A)

As evidenced by the graph above, the average life length is short for all states with a low initial performance value. For instance, with initial performance value of 1 (only 1/5 of the mean shock intensity) most states rapidly encountered a shock that ended their lives. Fragile states lived on average 16.59 ticks, resilient states an average of 7.5 ticks, and antifragile states an average of 15.89 ticks. In fact, it is not until states experience and initial performance value of 3 that antifragile states on average live longer (19.5 ticks) than both fragile states (19.21 ticks) and resilient states (19.04 ticks). From this observation, it can be deduced that when states have low initial ability to survive a shock (initial performance) it matters little whether they have the capacity to build back better if they survive. Mostly, they just do not survive under these conditions.

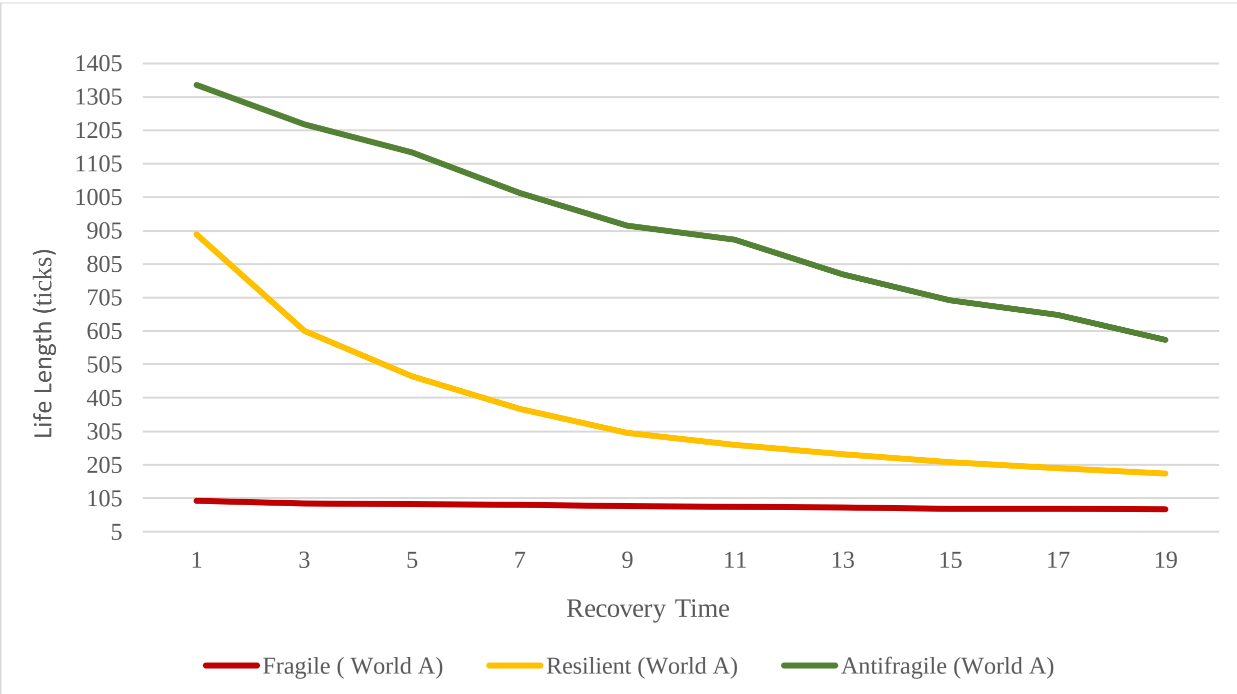
Average life length begins to diverge substantially by the time initial performance reaches a value of 5. At this point antifragile states begin to substantially pull away from the other categories, with a markedly longer average life length (145.24 ticks) than both fragile states (27.96 ticks) and resilient states (32.38 ticks). In fact, at an initial performance value of 5, we can actually see behavior consistent with the literature on fragility and antifragility. That is, antifragile states on average survive longer than resilient states, and resilient states survive on average longer than fragile states. This behavior holds true throughout all remaining initial performance values.

The maximum divergence between average life length for the fragile and resilient states is reached when initial performance is at its greatest value, 19. At the highest level of initial performance (19), the average life length is 183.07 ticks for fragile states, 1002.92 for resilient states, and 1795.82 for antifragile states. Thus, even a very high level of initial performance is not sufficient to provide for a very long life for the fragile states, though the average is much higher than with lower initial performance. By contrast, with a high initial performance, nearly all of the antifragile states live to the end of the simulation run (2000 ticks).

Finally, the maximum divergence between the average life length for antifragile states and resilient states is reached when initial performance is 13.

Figure 13 below examines the impact of antifragility, resilience, and fragility on a state’s life length relative to recovery time. Recovery time is the amount of time it takes a state to recover after encountering a shock in the environment. The model runs reveal important non-linear interactions between the degree of state fragility/antifragility and recovery time in shaping the average life length of the state.

Figure 13: Impact of Antifragility, Resilience, and Fragility on Life Length with Respect to Recovery Time (World A)



For all states, the average life length decreases as the time it takes for the state to recovery from a shock increases with one notable exception. The average life length of fragile states is not significantly impacted by an increase in recovery time. In fact, the range for average life length is 97.16 at a minimum recovery time (1) and 71.79 at a maximum recovery (19).

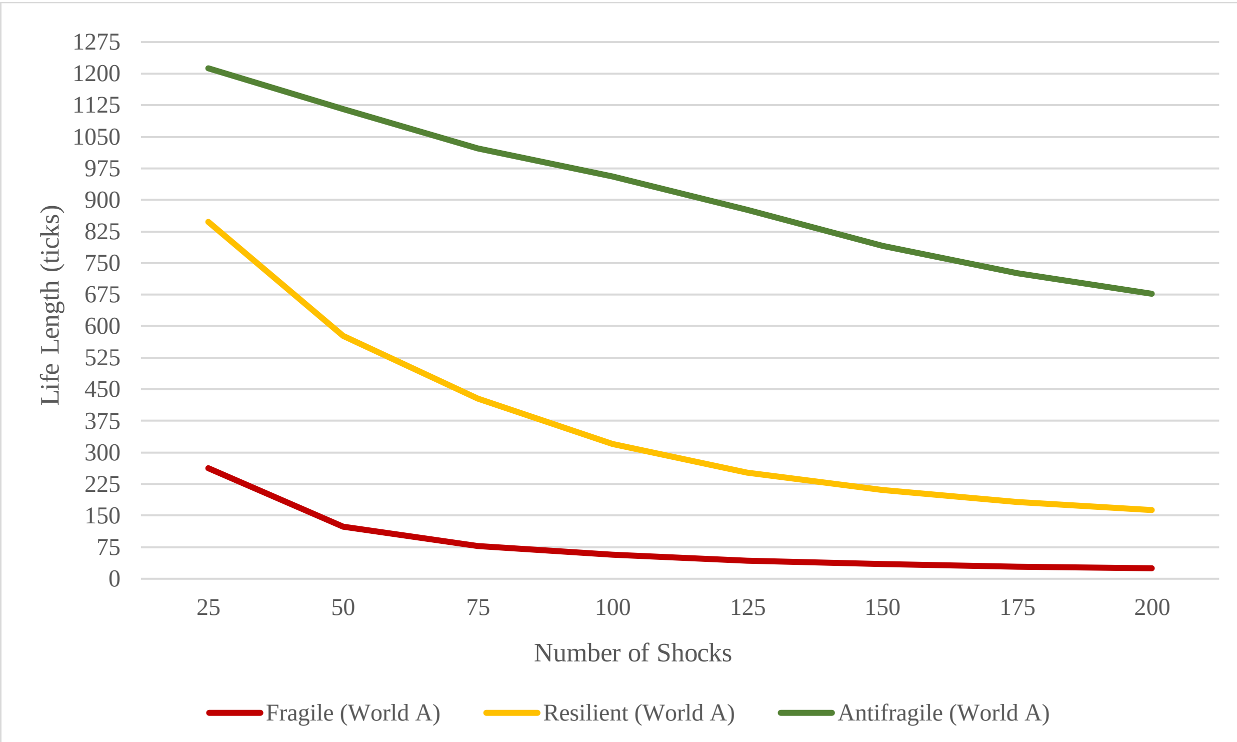
Between the minimum recovery time (1) and a maximum recovery time (19), resilient states lived on average between 893.86 ticks (1) and 178.8 ticks (19), respectively. This behavior again demonstrates an inverse relationship between a resilient state's recovery time and average life length. Of note, however, the average life length of resilient states steadily decreases until recovery time equals 9. From recovery time equals 9 to the maximum recovery time (19), the average life length of resilient states does not seem to significantly decrease, indicating that the increase in recovery time does not have a significant impact in the reduction of average life length for resilient states from recovery time equals 9 to the maximum recovery time (19).

Finally, antifragile states far outlived their resilient and fragile counterparts with average life ranging from 1340.92 ticks at the minimum recovery time (1) and 578.57 ticks at the maximum recovery time (19). Again, the inverse relationship between recovery time and average life length is detected, as the average life length of the antifragile state seems to steadily decrease throughout each recovery time value.

The greatest point of divergence between fragile states and resilient states occurs at a recovery time value of 3; whereas the greatest point of divergence between resilient states and fragile states occurs at a recovery value of 5. Overall, recovery time matters to the resilient and antifragile in World A, and less so with fragile states.

Figure 14 below examines the impact of antifragility, resilience, and fragility on a state's life length relative to the number of shocks in the environment. Recall, that the greater the number of shocks in the environment, the more chaotic the environment is. The model runs reveal important non-linear interactions between the degree of state fragility/antifragility and the number of shocks in the environment in shaping the average life length of the state.

Figure 14: Impact of Antifragility, Resilience, and Fragility on Life Length with Respect to Number of Shocks (World A)



For all states, the average life length decreases as the number of shocks in the environment increase, thus indicating an inverse relationship between the number of shocks in the environment and life length. At the lowest number of shocks in the environment (25), the average life length for fragile states is 262.66 ticks, 847.86 ticks for resilient states, and 1212.68 ticks for antifragile states. The maximum divergence in life length between fragile states and resilient states occurs at 25 shocks, and the greatest divergence in life length between resilient states and antifragile states occurs at 100 shocks.

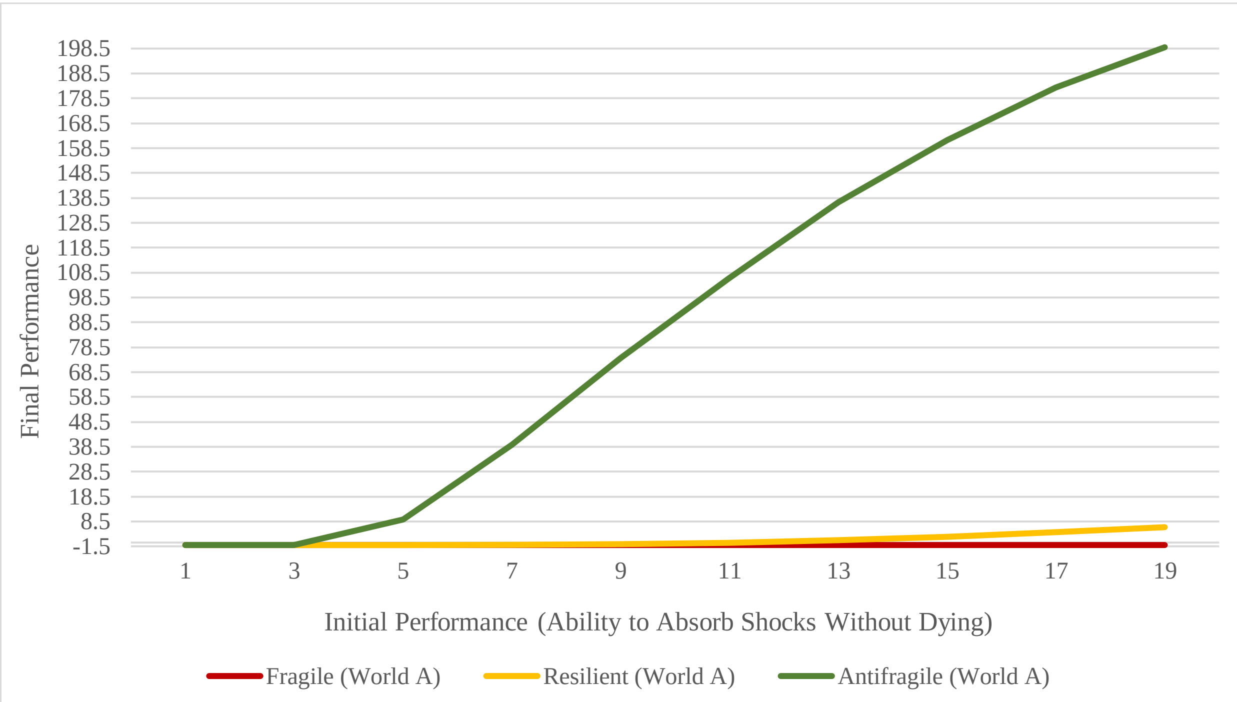
The average life length for fragile states decreases substantially from 262.66 ticks at the lowest number of shocks in the environment (25) to 24.94 ticks at the highest number of shocks in the environment (200). Similarly, the average life length for resilient states decreases substantially from 847.86 ticks at the lowest number of shocks in the environment (25) to 163.24 ticks at the highest number of shocks in the environment (200). Finally, antifragile states follow a similar pattern by decreasing their average life length roughly in half from 1212.68 ticks at lowest level of shocks in the environment (25) to 677.1 ticks at the highest level of shocks in the environment (200). Recall that in World A, both the initial percent-learn and initial percent-forget values were held constant at a value of 0. Under these circumstances, we do not observe an expected behavior of antifragile states gaining (living longer) from an increase in the number of shocks because they are not learning (or forgetting) capacity, and therefore the advantage of frequent shocks as a way to develop antifragility is less valuable for states.

Finally, when both the *initial percent-learn* variable and *initial percent-forget* variable are set to 0 as they are in World A, then fragile states have an average life length of 82.11 ticks. Resilient states have an average life length of 234.37 ticks, and antifragile states have an average life length of 907.92 ticks. Again, the three state types follow a behavior which we would expect. That is, antifragile states outlive resilient states, and resilient states outlive antifragile states.

Dependent Variable, Final Performance

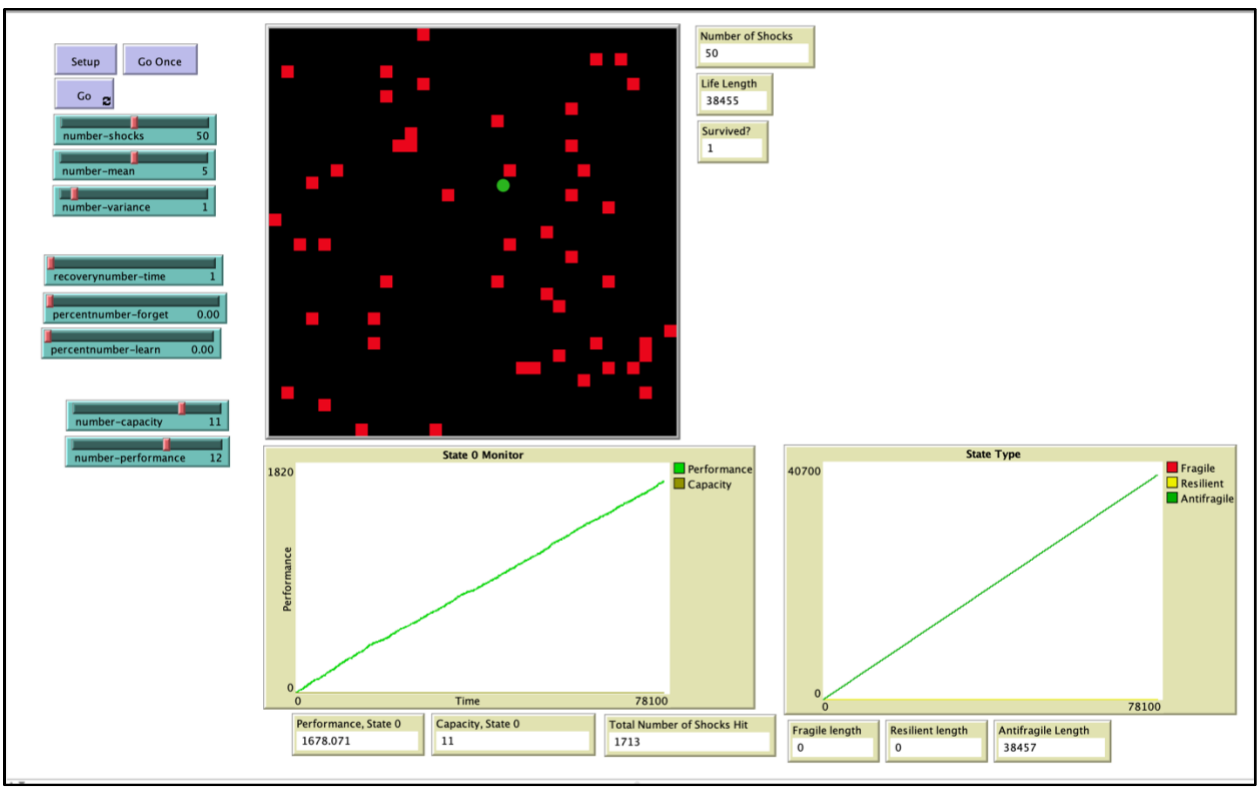
Figure 15 below examines the impact of antifragility, resilience, and fragility on the state's final performance value relative to its initial performance value. Final performance value is identical to initial performance value in that they both are defined as the ability of the agent to absorb a shock without dying, with the primary difference being the time it is recorded. Initial performance value is a value the agent is endowed with at the start of the simulation; final performance value is the agent's recorded performance value at the time of death or the end of the simulation (2000 ticks). The model runs reveal important non-linear interactions between the degree of state fragility / antifragility and the initial performance value in shaping the agent's average final performance.

Figure 15: Impact of Antifragility, Resilience, and Fragility on Final Performance Value with Respect to Initial Performance Value (World A)



The final performance value is small for all states with low initial performance (1 and 3). All three state types final performance results in a value of -1, indicating that none of the states are able to survive. In fact, none of the fragile states carry an average final performance value greater than -1, and it is only at an initial performance value of 13 whereby resilient states have a positive average final performance value (0.86) and are able to survive. The positive, average final performance value for antifragile states (9.21) occurs a little earlier than that of the resilient state, occurring at an initial performance value of 5. What is most interesting about this initial performance value for the antifragile state is that it begins to rapidly pull away from its fragile and resilient state counterparts, demonstrating a “break-away” type behavior. This “break-away” or take-off phenomenon becomes readily apparent among antifragile states whereby the state performance gets extremely large. As a result, these types of “super antifragile” states are almost assured of survival versus the shocks in the world it encounters. Figure 16 below shows how an antifragile state in World A “breaks away” under the following initial conditions: number of shocks (50), number-mean (5), number-variance (1), recoverynumber-time (1), percentnumber-forget (0), percentnumber-learn (0), number-capacity (11), and number performance (12).

Figure 16: Single Run of Antifragile State Demonstrating “Break-Away” Behavior

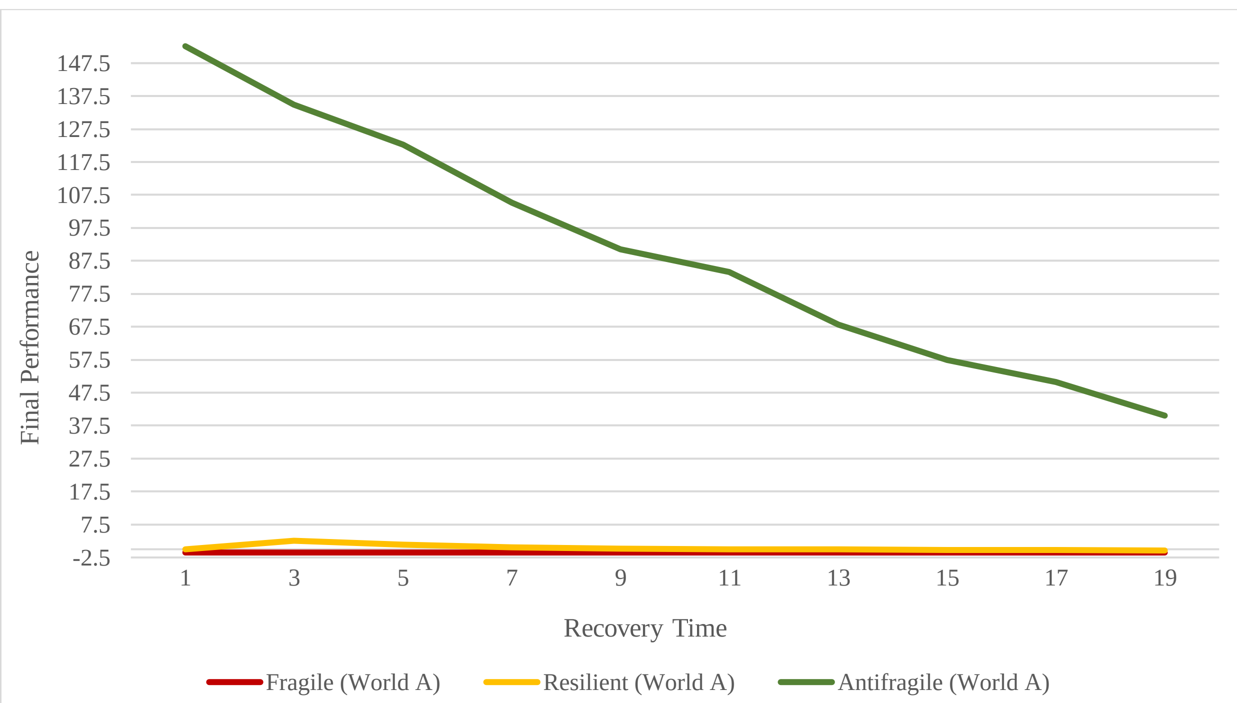


The maximum divergence between average life length for the fragile state and resilient state is reached when initial performance is 19, and the maximum divergence between average life length for antifragile states and resilient states is reached when initial performance is also 19.

At the highest level of initial performance (19), the final performance average is -1 for fragile states, 6.17 for resilient states, and 199.03 for antifragile states.

Figure 17 below examines the impact of antifragility, resilience, and fragility on the state's final performance value relative to recovery time. The model runs reveal important non-linear interactions between the degree of state fragility / antifragility and recovery time in shaping the state's average final performance value.

Figure 17: Impact of Antifragility, Resilience, and Fragility on Final Performance Value with Respect to Recovery Time (World A)



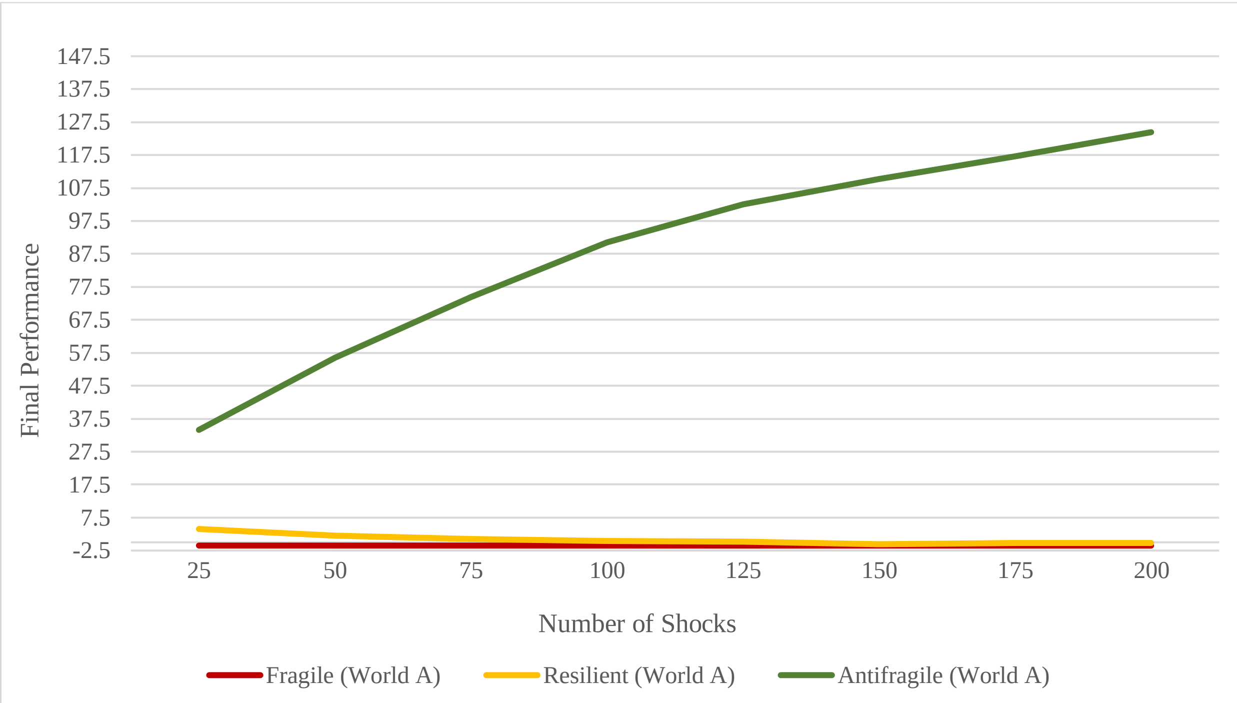
For each of the state types, the average final performance decreases with an increase in recovery time. The average final performance of both fragile states and resilient states is not significantly impacted by an increase in recovery time. Antifragile states, however, are significantly impacted by an increase in recovery time, with the average final performance steadily decreasing. For example, at the minimum recovery time (1), antifragile states' average final performance is 152.65. At the maximum recovery time (19), antifragile states' average final performance has been reduced to 40.55.

The maximum divergence between the average final performance for the fragile state and resilient state is reached when recovery time is 3; whereas the maximum divergence between the average final performance for the antifragile state and resilient state is when recovery time is 1.

At the highest level of recovery time (19), the final performance value is -1 for fragile states, -0.38 for resilient states, and 40.55 for antifragile states.

Figure 18 below examines the impact of antifragility, resilience, and fragility on the state's final performance value relative to the number of shocks in the environment. The model runs reveal important non-linear interactions between the degree of state fragility / antifragility and the number of shocks in the environment in shaping the average final performance value.

Figure 18: Impact of Antifragility, Resilience, and Fragility on Final Performance Value with Respect to Number of Shocks (World A)



For resilient and fragile states, the average final performance decreases with an increase in the number of shocks; however, antifragile states increase their final performance value with an increase in the number of shocks, demonstrating how antifragile states gain from experience. At the lowest number of shocks in the environment (25), fragile states have an average final performance of -1, resilient states have an average final performance of 4.04, and antifragile states have an average final performance of 34.11. At the highest number of shocks (200), fragile states have an average final performance of -1, resilient states have an average final performance of -0.23, and resilient states have an average final performance of 124.45.

The maximum divergence between final performance for the fragile and resilient states is reached when the number of shocks is 25. The maximum divergence between final performance for resilient states and antifragile states is reached when the number of shocks is 200.

WORLD A ANALYSIS CONCLUSION

The results of the World A experiment produce behavioral patterns one would expect to see based on the literature in Chapter 2. That is, antifragile states far outperform their resilient state and fragile state counterparts across the board in both categories: average life length and final performance. Similarly, resilient states outperform fragile states in both categories, although some categories are marginal when it comes to how much better resilient states do than fragile states.

In a world in which states are fixed as either antifragile, resilient, or fragile, such as this one, what is not observed is the anticipated behavior of antifragile states improving life length from an increase in the number of shocks in their environment. This behavior was not demonstrated when examining the number of shocks relative to average life length. In fact, antifragile states' average life length decreased, similar to its resilient state and fragile state counterparts. What is evidenced is that the final performance of the antifragile state is greater than that of the resilient and fragile states as the number of shocks increase. That is, antifragile states may not gain average life length from intensity of shocks in their environment, but they do fair better relative to average life length and final performance value than their resilient state and fragile state counterparts.

WORLD B RESULTS AND ANALYSIS

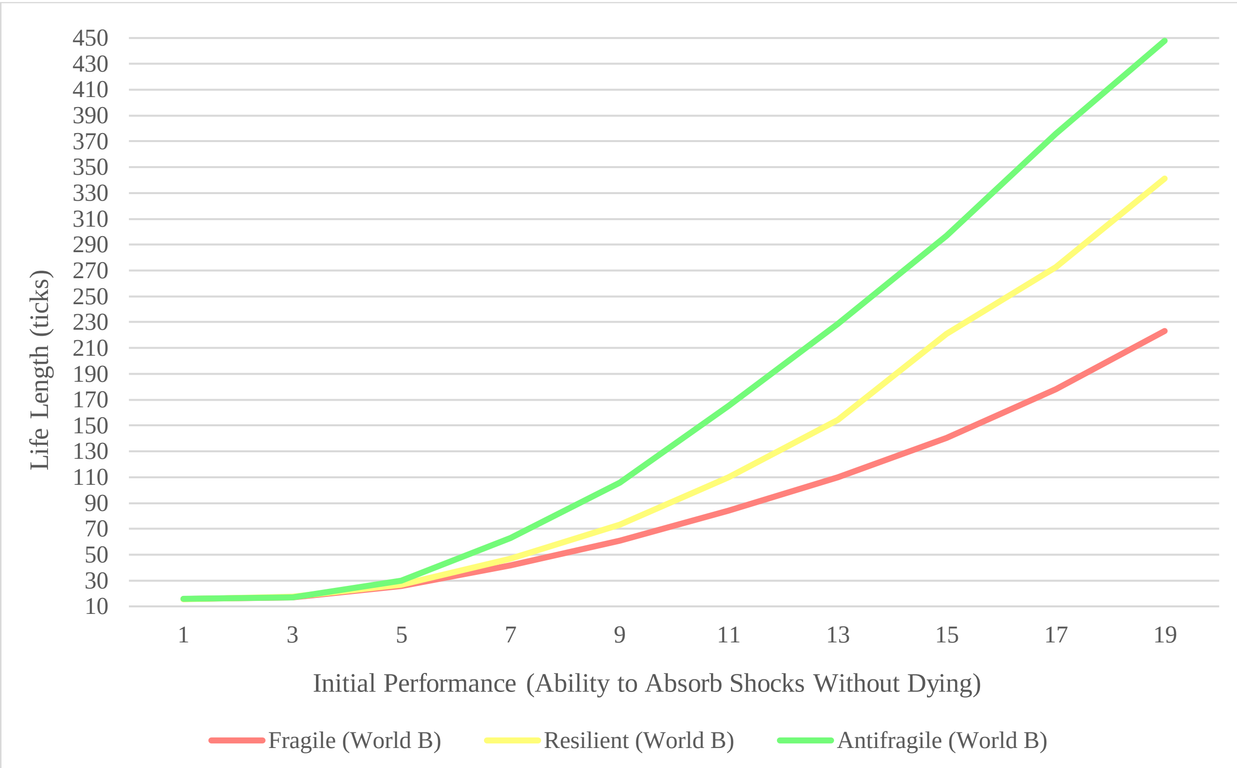
The experiments in World B seek to answer *what kind of world might be best for state survival and maintaining antifragility*? The final analysis of these experiments is overall consistent with that of World A. That is, antifragility is better than resilience and fragility. Where the results differ, however, is in understanding of what type of world maintains antifragility. The series of experiments in World B underscore the criticality of state learning and forgetting.

Recall that World B significantly differs from World A in two respects. First, percent-learn, and percent-forget have values greater than 0. Second, fragility, resilience, and antifragility are now simply initial values. That is, these experiments examine the impact of initial antifragility, resilience, and fragility on a series of dependent variables. As a result, these initial categories are dynamic and may change over the course of the experimental runs.

Dependent Variable, Life Length

Figure 19 below examines the impact of initial antifragility, resilience, and fragility on the state's average life length relative to initial performance value. The model runs reveal important non-linear interactions between the degree of initial state fragility / antifragility and the extent of state initial performance in shaping the state's average life length.

Figure 19: Impact of Initial Antifragility, Resilience, and Fragility on Life Length with Respect to Initial Performance (World B)



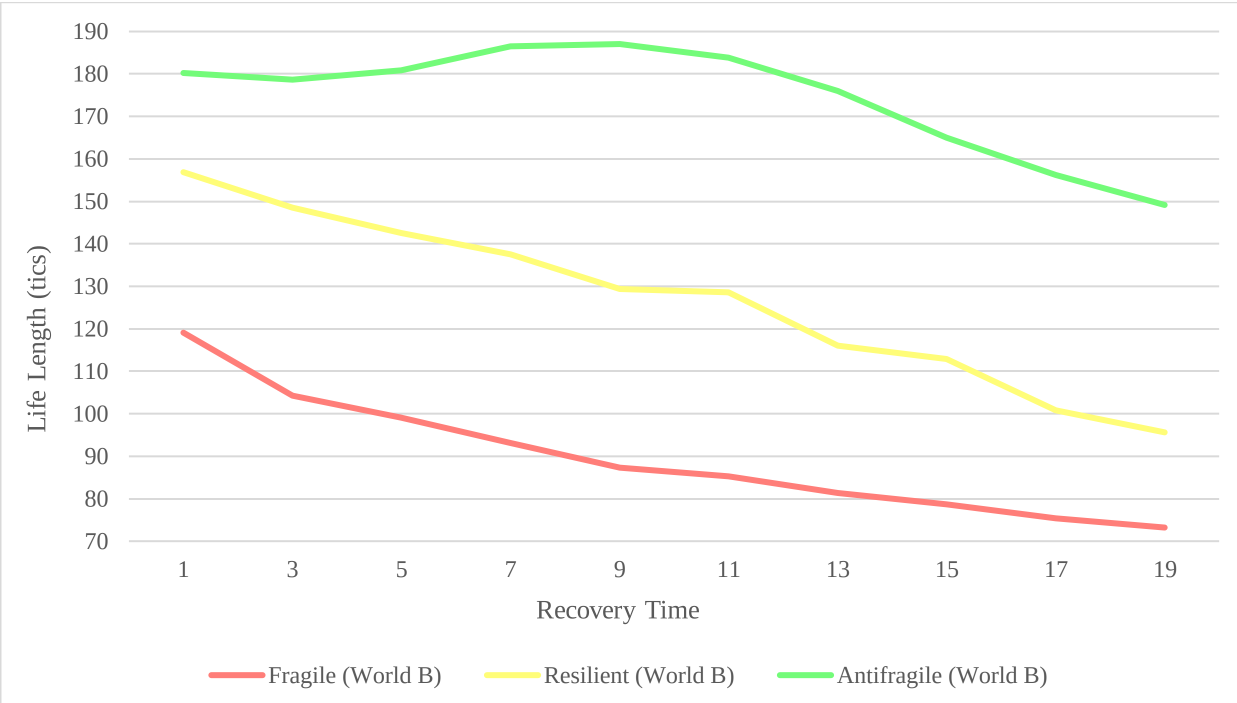
Average life length is short for all states with low initial performance. Similar to World A, with initial performance of 1 (only 1/5 of the mean shock intensity) most states rapidly encountered a shock that ended their lives. For example, the average life length for initially fragile states is 15.71 ticks. The average life length for initially resilient states is 15.55 ticks, and the average life length for initially antifragile states is 15.84 ticks. In fact, upon closer examination it is revelated that at the lowest initial performance value, initially fragile states narrowly outlive initially resilient states. When states have low initial ability to survive a shock (performance) then it matters little whether they have the capacity to build back better if they survive. Similar to those in World A, the states mostly just do not survive.

Average life length begins to diverge substantially by the time initial performance reaches a value of 7. At this point, all the states begin to noticeably pull away from one another.

The maximum divergence between average life length for the initially fragile states and initially resilient states is reached when initial performance is at its maximum value (19); similarly, the maximum divergence between average life length for the initially resilient states and initially antifragile states is reached when initial performance also at its maximum value (19). At the highest level of initial performance, average life length for initially fragile, initially resilient and initially antifragile states is 223.17 ticks, 341.19 ticks, and 447. 87 ticks, respectively.

Figure 20 below examines the impact of initial antifragility, resilience, and fragility on the state's average life length relative to recovery time. The model runs reveal important non-linear interactions between the degree of initial state fragility/antifragility and the extent of recovery time in shaping the state's average life length.

Figure 20: Impact of Initial Antifragility, Resilience, and Fragility on Average Life Length with Respect to Recovery Time (World B)



Both initially fragile and initially resilient states see a steady decrease of average life length with respect to recovery time. Initially antifragile states, however, seem to decline in average life length, increase, and then decline again over the various recovery periods.

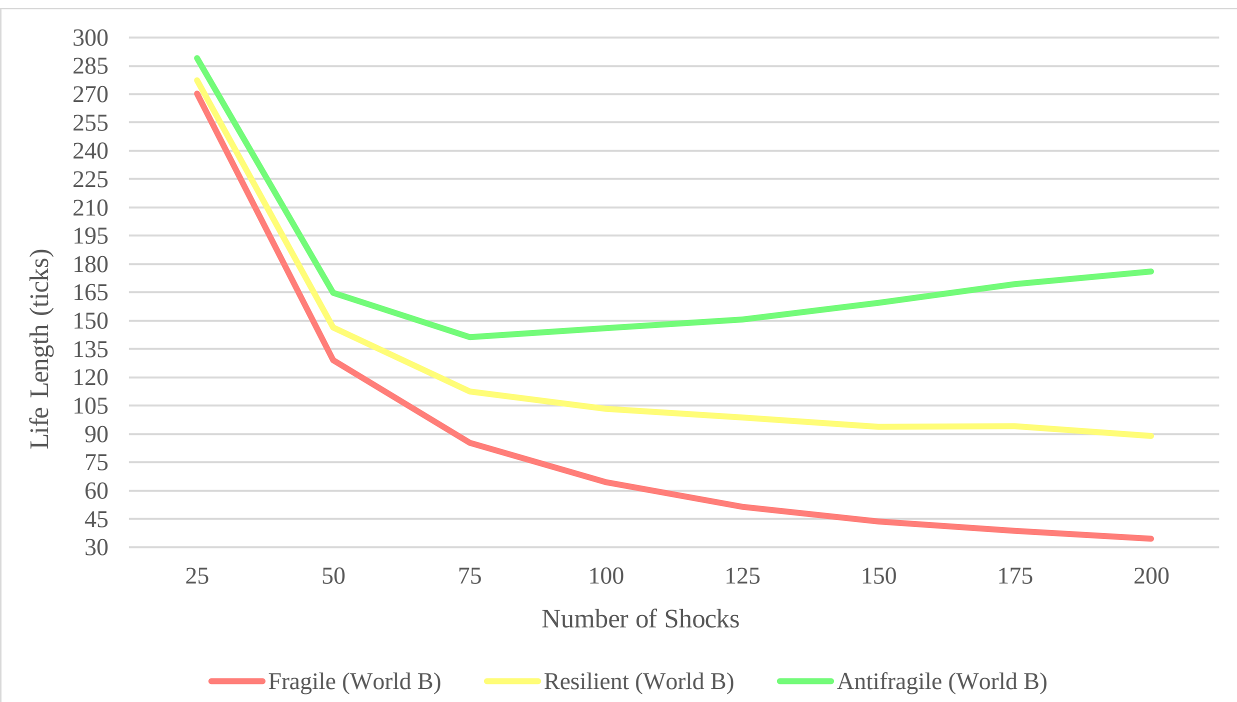
At the lowest recovery time (1), initially fragile states live on average 119.09 ticks; initially resilient states have an average life length of 156.88 ticks; and initially antifragile states have an average life length of 180.25 ticks. At the highest recovery time (19), initially fragile states live on average 73.21 ticks, whereas initially resilient states live on average 95.62 ticks. Finally, initially antifragile states live on average 149.16 ticks.

The greatest point of divergence between initially resilient states and initially fragile states occurs when recovery time is 7. The maximum point of divergence between initially antifragile states and initially resilient states occurs when recovery time is 13.

Overall, initially antifragile states live longer than resilient states and fragile states across all values of recovery time.

Figure 21 below examines the impact of initial antifragility, resilience, and fragility on the state's average life length relative to the number of shocks in the environment. The model runs reveal important non-linear interactions between the degree of initial state fragility/antifragility and the number of shocks in the environment in shaping the state's average life length.

Figure 21: Impact of Initial Antifragility, Resilience, and Fragility on Average Life Length with Respect to Number of Shocks (World B)



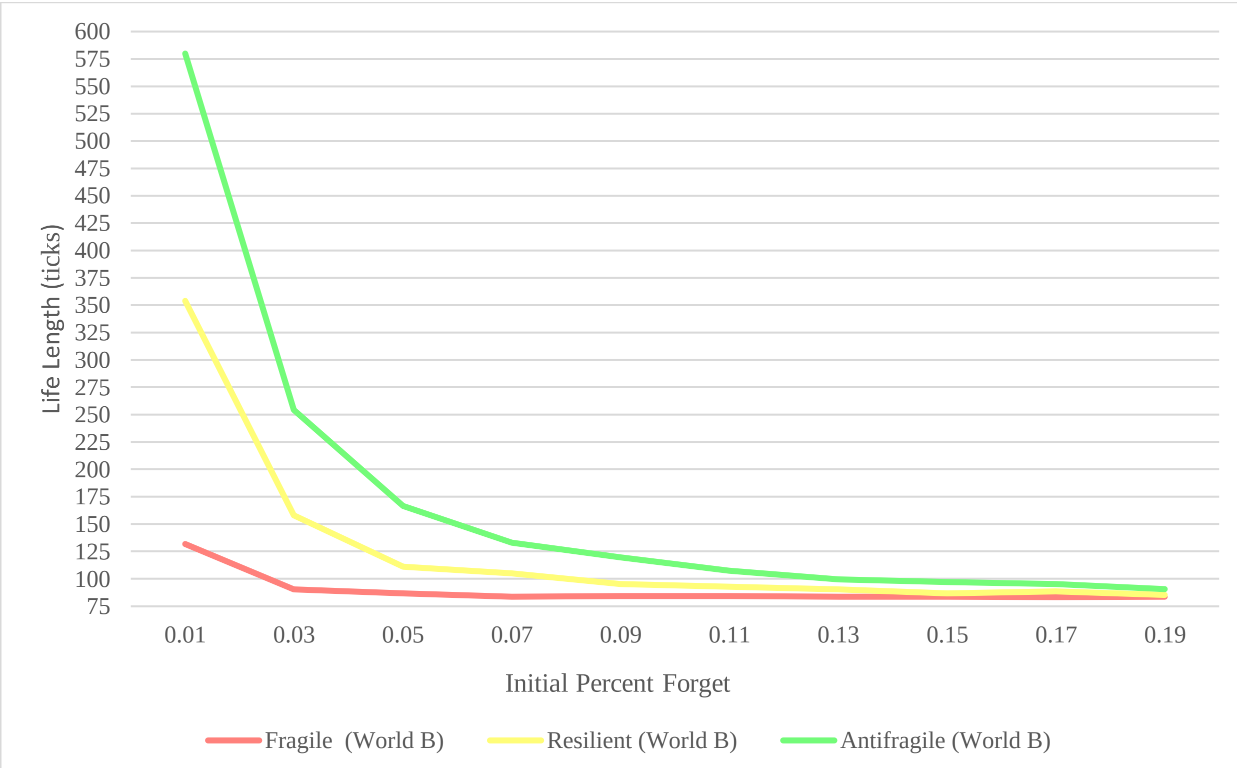
Both initially fragile states and initially resilient states steadily decrease in average life length with respect to the number of shocks in the environment. Initially antifragile states, too, see a decrease in average life length with respect to the number of shocks in the environment until it reaches 75 shocks in the environment. At this point, initially antifragile states begin to see an increase in average life length again. In fact, at the 100 shocks value, the average life length for an initially antifragile state is 145.97 ticks, and at the 200 shocks value, its life length increases to 176.08 ticks, demonstrating a behavior previously unseen in World A. That is, an increase in life length with an increase in the number of shocks in the environment for initially antifragile states. Furthermore, both resilient and fragile states see a decrease in average life length as the number of shocks increases in the environment.

With the lowest number of shocks in the environment (25), initially fragile states live on average 270.31 ticks; initially resilient states have an average life length of 277.36 ticks; and initially antifragile states have an average life length of 289.09 ticks. With the greatest number of shocks in the environment (200), initially fragile states live on average 34.49 ticks, whereas initially resilient states live on average 88.94 ticks. Finally, initially antifragile states live on average 176.08 ticks.

The greatest point of divergence between initially resilient states and initially fragile states occurs when shocks are 175. The maximum point of divergence between initially antifragile states and initially resilient states occurs when shocks are 200.

Figure 22 below examines the impact of antifragility, resilience, and fragility on the state's average life length relative to initial percent-forget. The model runs reveal important non-linear interactions between the degree of initial state fragility / antifragility and the initial percent-forget variable in shaping the state's average life length.

Figure 22: Impact of Initial Antifragility, Resilience, and Fragility on Average Life Length with Respect to Average Initial Percent-Forget (World B)



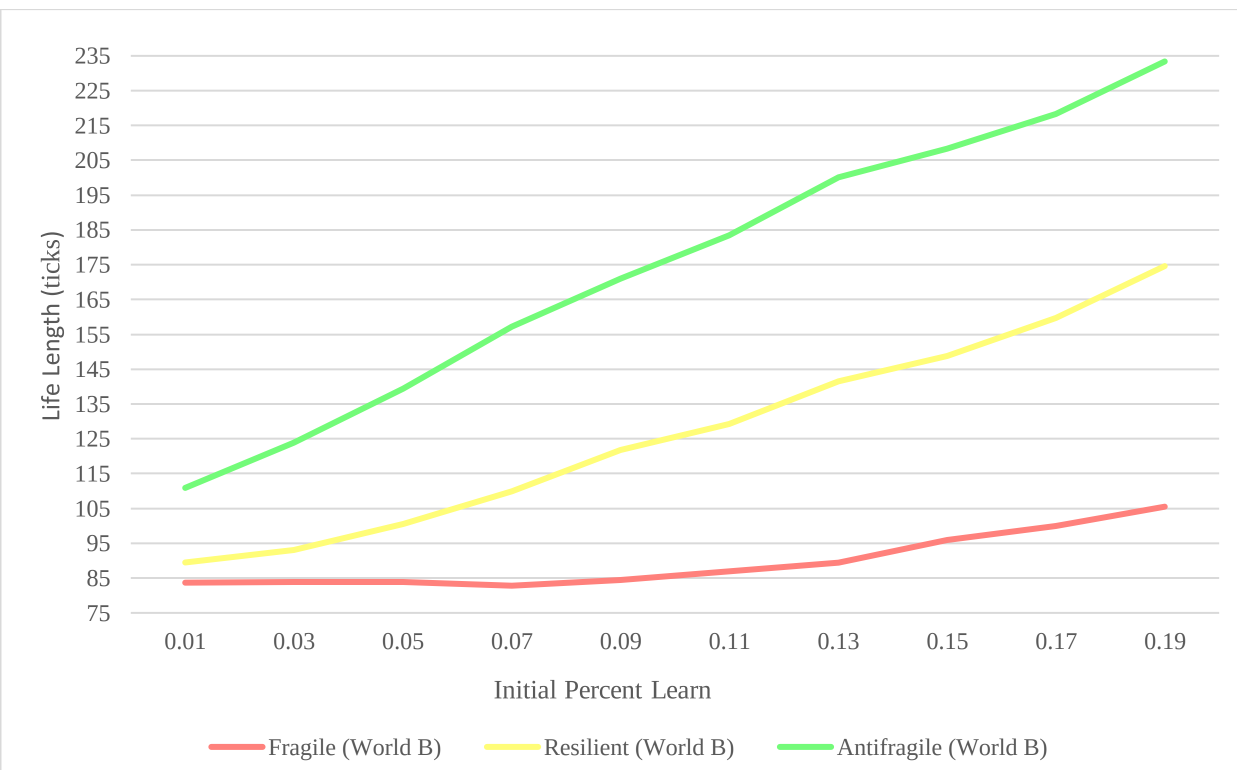
All states rapidly decrease of average life length with respect the initial percent-forget variable until the initial percent-forget variable is 0.07. The behavior then changes to a slight decrease in the average life length.

With the lowest value for initial percent-forget (0.01), initially fragile states live on average 131.94 ticks; initially resilient states have an average life length of 353.98 ticks; and initially antifragile states have an average life length of 579.89 ticks. With the largest percent-forget value (0.19), initially fragile states live on average 84.03 ticks, whereas initially resilient states live on average 85.45 ticks. Finally, initially antifragile states live on average 90.76 ticks.

The greatest point of divergence between initially resilient states and initially fragile states occurs when at the initial percent forgot value of 0.01. The maximum point of divergence between initially antifragile states and initially resilient states occurs when the initial percent-forget value is 0.01. It can be observed that a state's forgetfulness, that is the inability to learn from past experience, has a substantial impact on its average life length despite the state type.

Figure 23 below examines the impact of antifragility, resilience, and fragility on the state's average life length relative to initial percent-learn. The model runs reveal important non-linear interactions between the degree of initial state fragility / antifragility and the initial percent-learn variable in shaping the state's average life length.

Figure 23: Impact of Initial Antifragility, Resilience, and Fragility on Average Life Length with Respect to Average Initial Percent-Learn (World B)



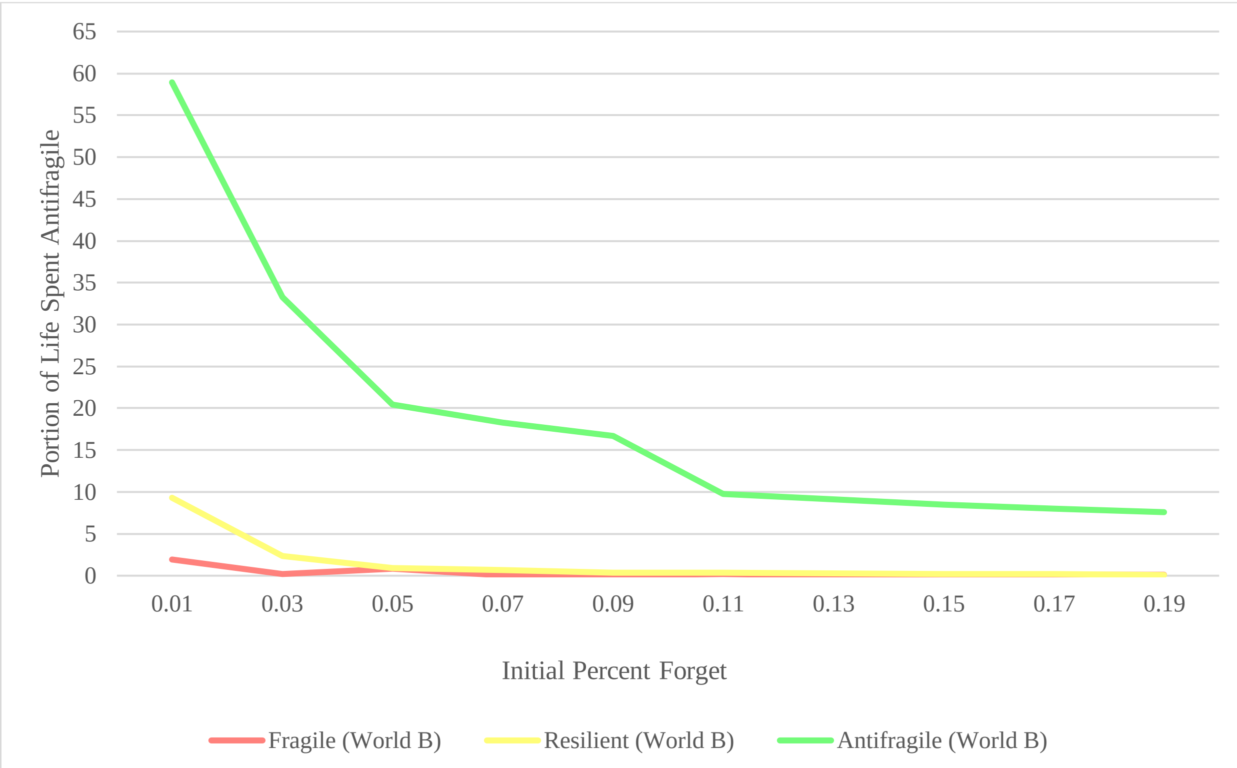
The result of this experiment reveal that all states see an increase in average life length with respect the initial percent-learn variable.

With the lowest value for initial percent-learn (0.01), initially fragile states live on average 83.73 ticks; initially resilient states have an average life length of 89.49 ticks; and initially antifragile states have an average life length of 110.91 ticks. With the largest percent - learn (0.19), initially fragile states live on average 105.51 ticks; whereas, initially resilient states live on average 174.62 ticks. Finally, initially antifragile states live on average 233.39 ticks.

The greatest point of divergence between initially resilient states and initially fragile states occurs when at the initial percent-forget value of 0.19. The maximum point of divergence between initially antifragile states and initially resilient states occurs when the initial percent-forget value is 0.15.

Similar to the results from the previous experiment (percent-forget), learning matters a great deal to all state types. One way to understand how important learning and forgetting is to states in World B is to examine the impact of initial antifragility, resilience, and fragility on the state's average portion of life spent being antifragile relative to initial percent-learn and initial percent-forget. In other words, what portion of a an initially antifragile state, initially resilient state and initially fragile state's life is spent being antifragile relative to its percent-forget and percent-learn values?

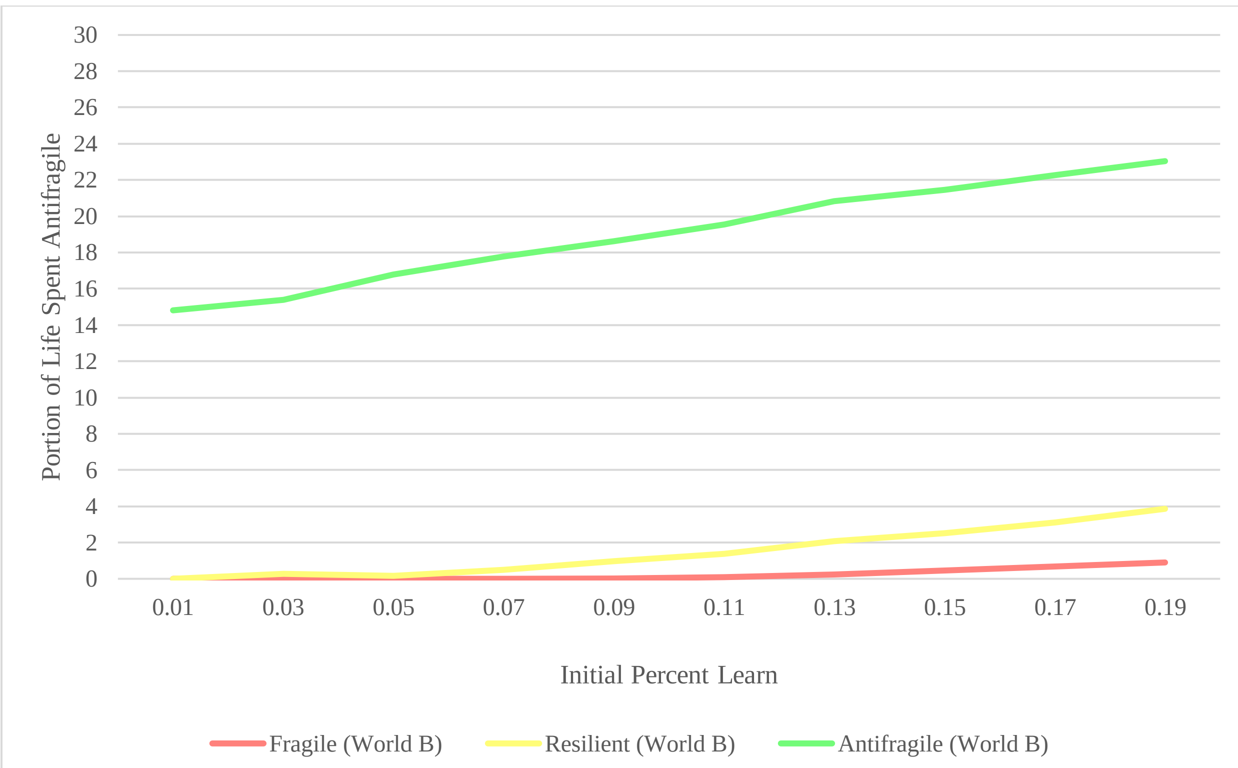
Figure 24: Impact of Initial Antifragility, Resilience, and Fragility on the Average Portion of Time Spent being Antifragile with Respect to Percent-Forget (World B)



All three state types see a decrease in the average portion of their life spent antifragile with respect to an increase with the initial percent-forget value. That is the more forgetful a state is the less time it spends being antifragile over the course of its lifetime. At the lowest initial percent-forget value (0.01), the portion of time spent being antifragile is 1.93 for initially fragile states, 9.31 for initially resilient states, and 58.93 for initially antifragile states. At the highest initial percent-forget value (0.19), the portion of time spent being antifragile is 0.10 for initially fragile states, 0.08 for initially resilient states, and 7.59 for initially antifragile states.

The greatest point of divergence between initially resilient states and initially fragile states occurs at the when initial percent-forget is at its lowest value (0.01). Finally, the maximum point of divergence between initially antifragile states and initially resilient states also occurs when initial percent-forget is at its lowest value (0.01).

Figure 25: Impact of Initial Antifragility, Resilience, and Fragility on the Average Portion of Time Spent being Antifragile with Respect to Initial Percent-Learn (World B)



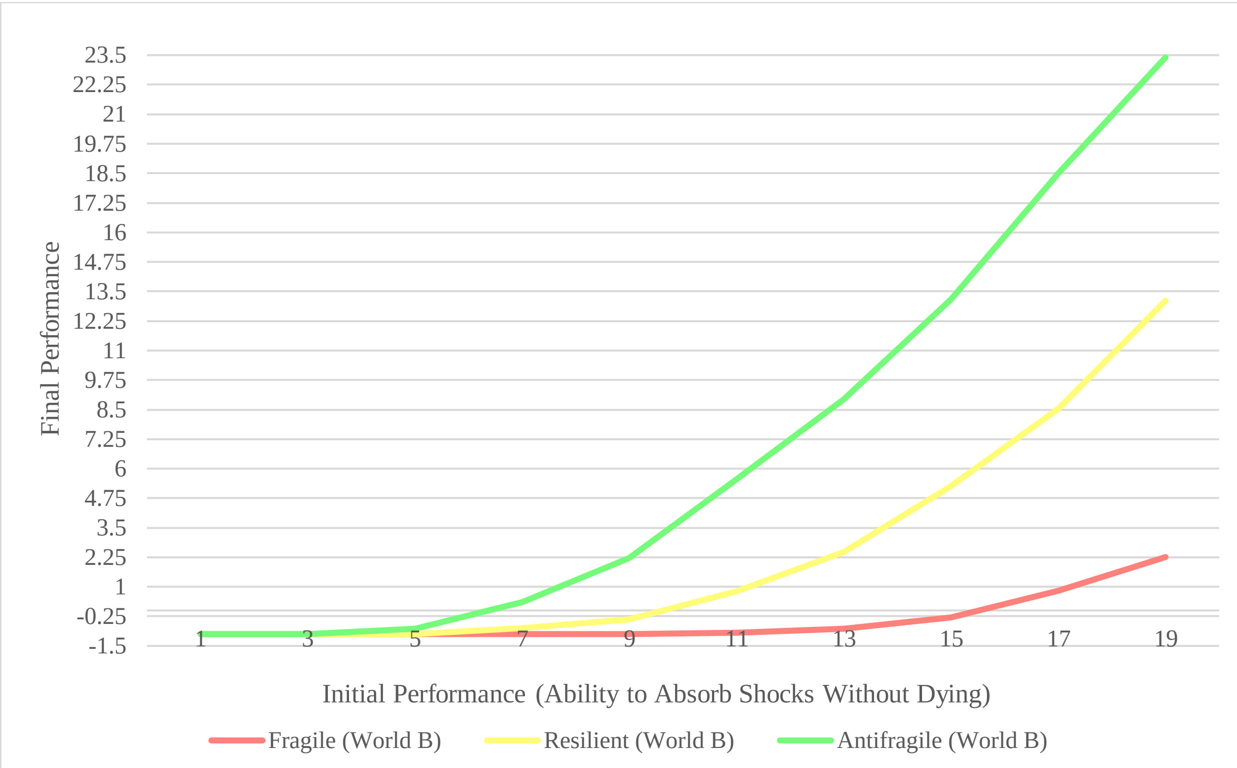
Fragile states, resilient states, and antifragile states all increase the average portion of their life spent antifragile with respect to an increase with the initial percent-learn value. Converse to Percent-Forget, when states increase their learning, they increase the portion of time that is spent being antifragile? At the lowest initial percent-learn value (0.01), the portion of time spent being antifragile is 0 for initially fragile states, 0 for initially resilient states, and 14.81 for initially antifragile states. At the highest initial percent-learn value (0.19), the portion of time spent being antifragile is 0.9 for initially fragile states, 3.86 for initially resilient states, and 23.04 for initially antifragile states.

The greatest point of divergence between initially resilient states and initially fragile states occurs at the when initial percent-learn is at its highest value (0.19). Finally, the maximum point of divergence between initially antifragile states and initially resilient states also occurs when initial percent-learn is at its highest value (0.19).

Dependent Variable, Final Performance

Figure 26 below examines the impact of antifragility, resilience, and fragility on the state's average final performance value relative to the initial performance. The model runs reveal important non-linear interactions between the degree of initial state fragility / antifragility and the initial performance in shaping the state's average final performance.

Figure 26: Impact of Initial Antifragility, Resilience, and Fragility on Average Final Performance with Respect to Initial Performance (World B)

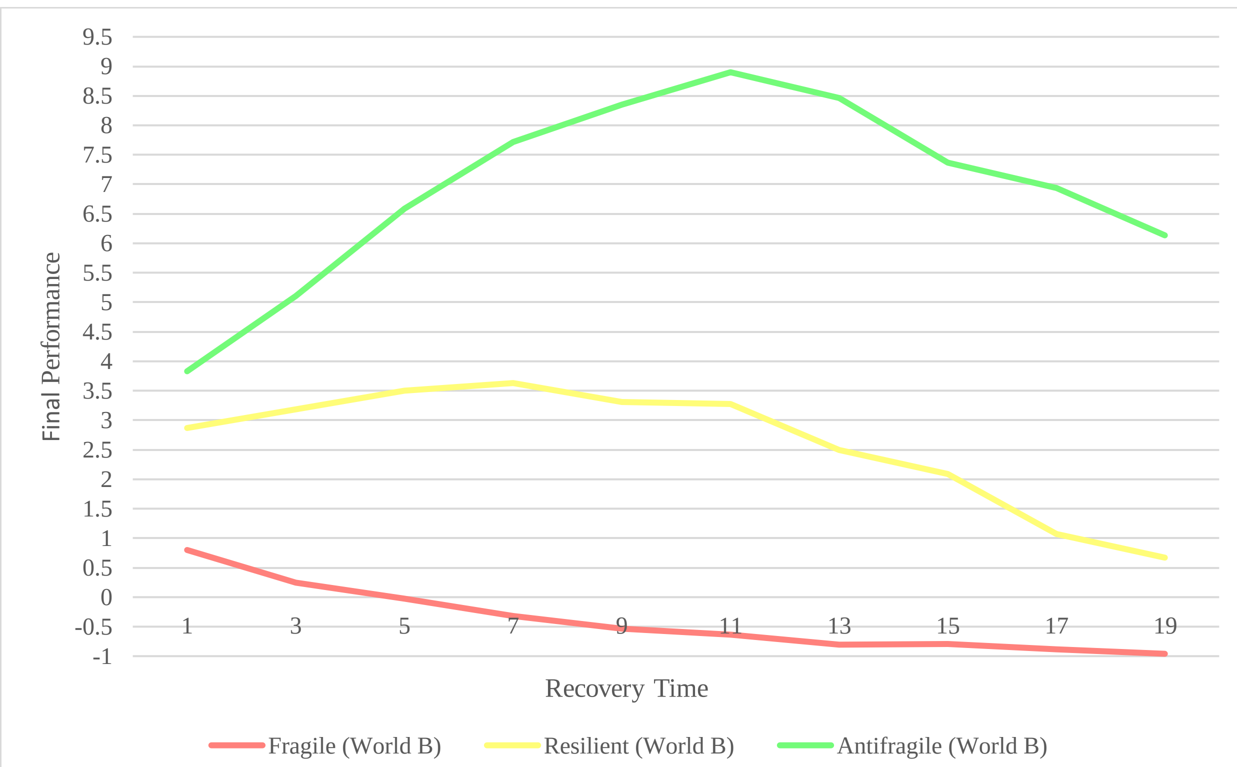


All states rapidly increase their final performance value with respect to an increase in their initial performance variable. In other words, the better endowed the state is with its initial performance, the better off it will end. With the lowest value for initial performance (1), all three state types have a final average performance value of -1. With the largest initial performance value (19), initially fragile states have an average final performance of 2.26; whereas, initially resilient states have a final average performance of 13.11. Finally, initially antifragile states have an average final performance of 23.14.

The greatest point of divergence between initially resilient states and initially fragile states occurs when the initial performance value is 19. The maximum point of divergence between initially antifragile states and initially resilient states also occurs when the initial performance value is 19.

Figure 27 below examines the impact of antifragility, resilience, and fragility on the state's average final performance value relative to recovery time. The model runs reveal important non-linear interactions between the degree of state fragility / antifragility and the recovery time in shaping the state's average final performance.

Figure 27: Impact of Initial Antifragility, Resilience, and Fragility on Average Final Performance with Respect to Recovery Time (World B)



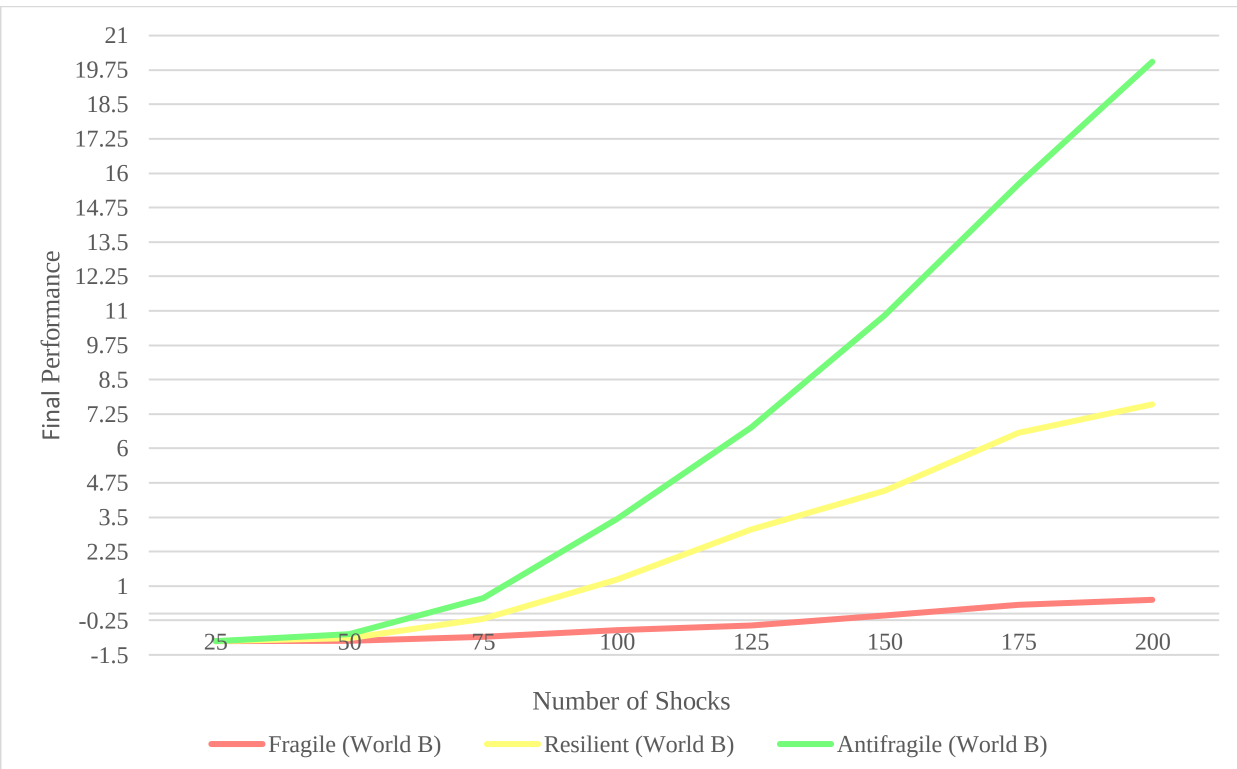
Both initially resilient and initially fragile states increase their final performance with respect to an increase in recovery time until they reach a certain point, whereby final performance begins to decline again. For initially resilient states, the final performance increases until it recovery time reaches 11. At this point, the final performance begins to decrease for resilient states. Similarly, initially antifragile states increase their final performance value with respect to an increase in recovery time until recovery time reaches a value of 13. Final performance for initially antifragile states begins to decrease with an increase in recovery time after this point. The curved behavior seen in the resilient state and antifragile state demonstrates that while a state is recovering it is not forgetting. The resilient states and the antifragile states in particular are gaining from longer recovery periods because they are able to stay antifragile and not forget as much. Finally, initially fragile states steadily decrease their final performance with respect to an increase in recovery time.

With the lowest value for recovery time (1), initially fragile states have an average final performance value of 0.80; initially resilient states possess an average final performance value of 2.87, and initially antifragile states have an average final performance value of 3.83. With the largest initial performance value (19), initially fragile states have an average final performance value of -0.96; whereas initially resilient states possess a final average performance value of 0.67. Finally, and most notably, initially antifragile states have an average final performance of 6.14, a final average performance value almost double that of the average final performance value of 3.83 at the lowest recovery time value.

The greatest point of divergence between initially resilient states and initially fragile states occurs when recovery time is 7. The maximum point of divergence between initially antifragile states and initially resilient states occurs when recovery time is 13.

Figure 28 below examines the impact of initial antifragility, resilience, and fragility on the state's average final performance value relative to the number of shocks in the environment The model runs reveal important non-linear interactions between the degree of state fragility / antifragility and the number of shocks in the environment in shaping the state's average final performance.

Figure 28: Impact of Initial Antifragility, Resilience, and Fragility on Average Final Performance with Respect to the Number of Shocks in the Environment (World B)

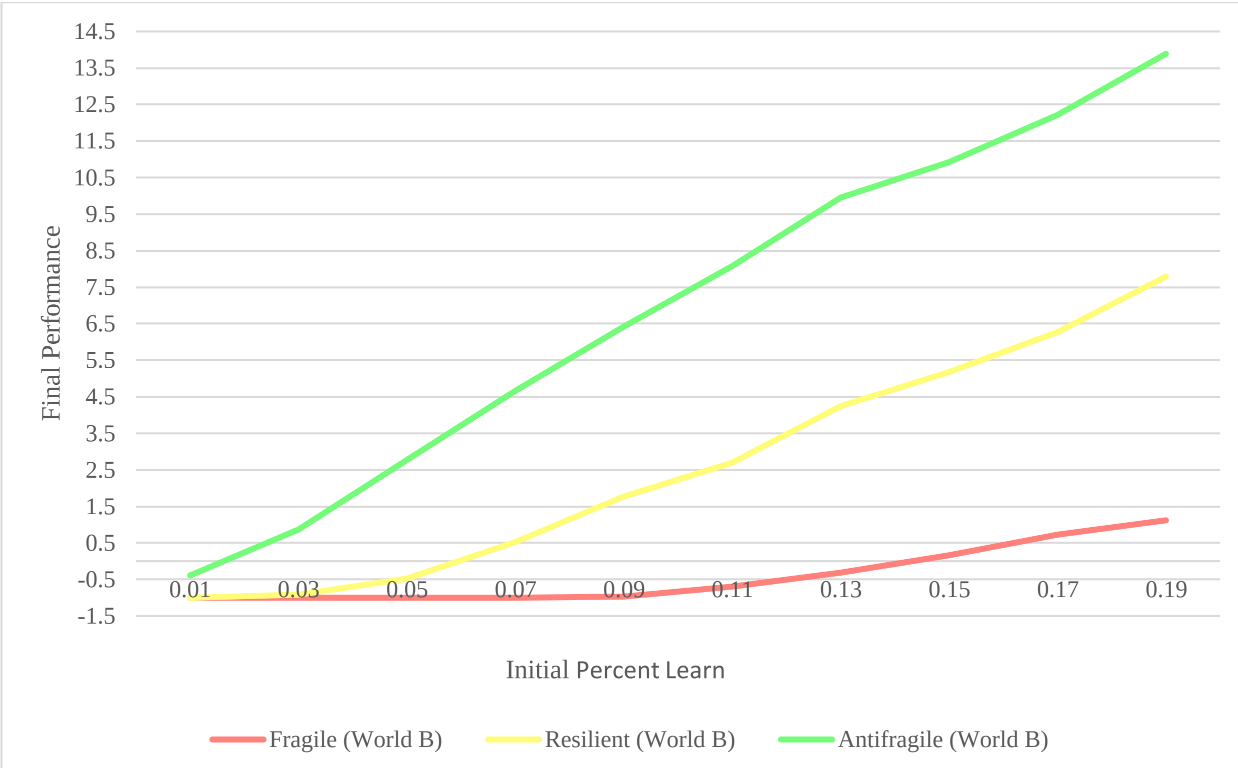


All state types increase their final performance with respect to an increase in the number of shocks in the environment until they reach a certain point, although the rate of increase varies by initial state. For example, initially fragile states' average final performance steadily increases incrementally, with a range of values of -1 at the lowest number of shocks in the environment (25) to an average final performance value of 0.50 at the highest number of shocks in the environment (200). Initially resilient states possess an average final performance value of -1 when there are the lowest number of shocks in the environment (25) and possess an average final performance of 7.6 when the environment has the highest number of shocks in the environment (200). Finally, initially antifragile states possess an average final performance value of -1 when the environment has the lowest number of shocks (25) and possesses an average final performance value of 20.05 when the environment has the greatest number of shocks in the environment (200).

The greatest point of divergence between initially resilient states and initially fragile states occurs when the number of shocks in the environment is 200. The maximum point of divergence between initially antifragile states and initially resilient states occurs when the number of shocks in the environment is 200. Upon deeper examination, this reflects the fact that no matter its initial characteristics, a state can become antifragile through repeated interaction with shocks in this simulation, particularly when forgetting is low, and learning is high. For a state to interact with enough shocks to become antifragile, shocks need to appear with sufficient frequency, hence an advantage for 200 shock environments.

Figure 29 below examines the impact of initial antifragility, resilience, and fragility on the state's average final performance value relative to the initial percent-learn value. The model runs reveal important non-linear interactions between the degree of initial state fragility / antifragility and the initial percent-learn value in shaping the state's average final performance.

Figure 29: Impact of Initial Antifragility, Resilience, and Fragility on Average Final Performance with Respect to the Initial Percent-Learn Value (World B)

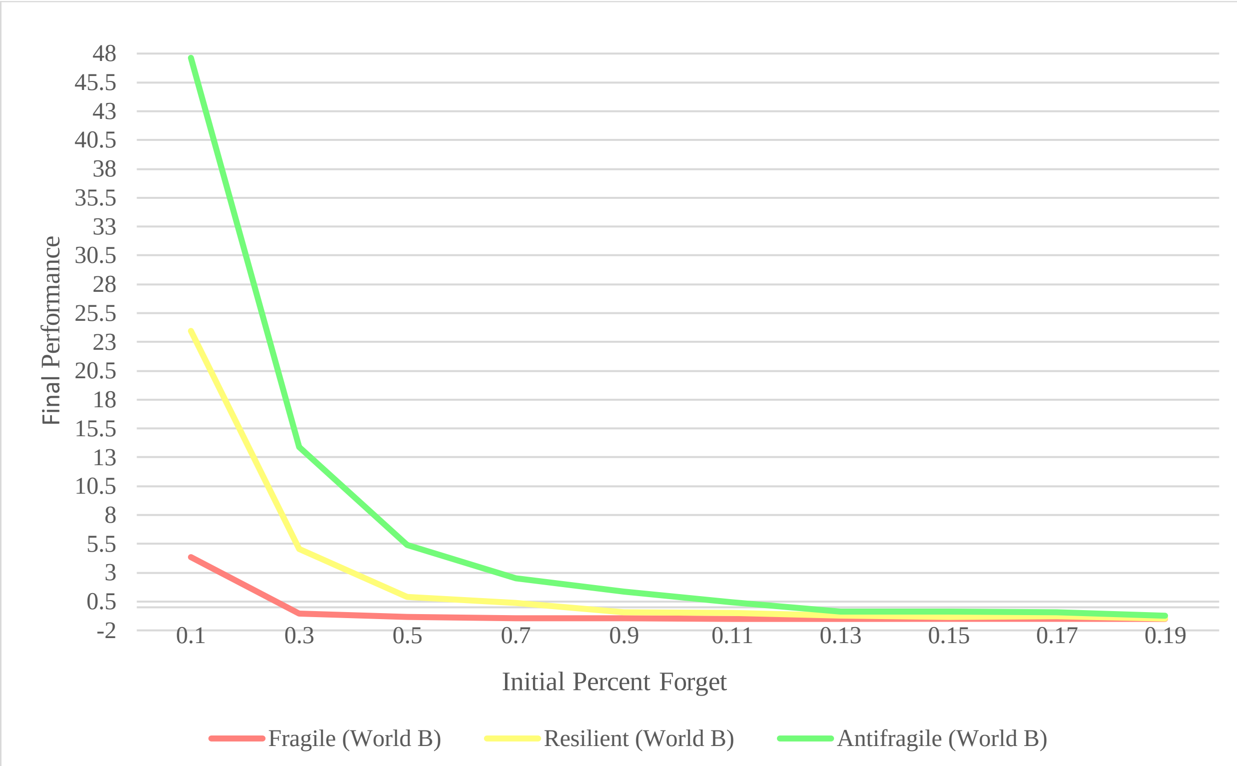


All state types increase their final performance with respect to an increase the initial percent-learn value. For example, initially fragile states' average final performance steadily increases from an average final performance value of-1 at the lowest initial percent-learn value (0.01) to an average final performance value of 1.12 at the greatest initial percent-learn value (0.19). Initially resilient states possess an average final performance value of -1 when there are the lowest initial percent-learn value (0.01) and possess an average final performance of 7.79 at the highest initial percent-learn value (0.19). Finally, initially antifragile states possess an average final performance value of -0.39 at the lowest initial percent value (0.01) and possesses an average final performance value of 13.89 at the highest initial percent value (0.19).

The greatest point of divergence between initially resilient states and initially fragile states occurs at the highest initial percent-learn value. The maximum point of divergence between initially antifragile states and initially resilient states also occurs at the highest initial percent-learn value (0.19).

Figure 30 below examines the impact of initial antifragility, resilience, and fragility on the state's average final performance value relative to the initial Percent-Forget value. The model runs reveal important non-linear interactions between the degree of initial state fragility / antifragility and the initial percent-forget value in shaping the state's average final performance.

Figure 30: Impact of Initial Antifragility, Resilience, and Fragility on Average Final Performance with Respect to the Initial Percent-Forget Value (World B)



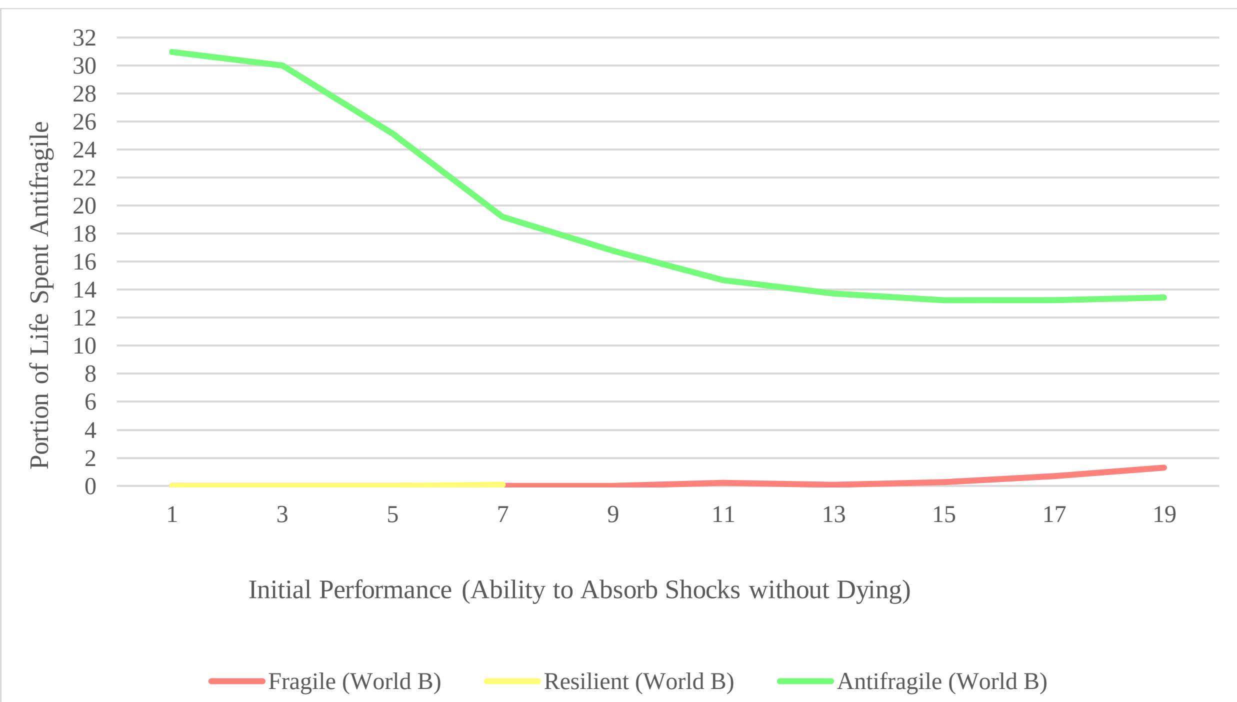
All state types significantly decrease their final performance with respect to an increase the initial percent-forget value. For example, initially fragile states' average final performance steadily decreases from an average final performance value of 4.35 at the lowest initial percent-forget value (0.01) to an average final performance value of -1 at the greatest initial percent-forget value (0.19). Initially resilient states possess an average final performance value of 23.96 when there are the lowest initial percent-learn value (0.01) and possess an average final performance of -0.97 at the highest initial percent-learn value (0.19). Finally, initially antifragile states possess an average final performance value of 47.63 at the lowest initial percent-forget value (0.01) and possesses an average final performance value of -0.73 at the highest initial percent-forget value (0.19).

The greatest point of divergence between initially resilient states and initially fragile states occurs at the highest initial percent-learn value (0.01). The maximum point of divergence between initially antifragile states and initially resilient states also occurs at the highest initial percent-learn value (0.19).

Dependent Variable, Portion of Life Spent Antifragile

Figure 31 below examines the impact of initial antifragility, resilience, and fragility on the state's average portion of life spent being antifragile relative to the initial performance. The model runs reveal important non-linear interactions between the degree of initial state fragility / antifragility and the initial performance in shaping the average portion of time the state spent being antifragile during its lifetime.

Figure 31: Impact of Initial Antifragility, Resilience, and Fragility on the Average Portion of Time Spent being Antifragile with Respect to Initial Performance (World B)

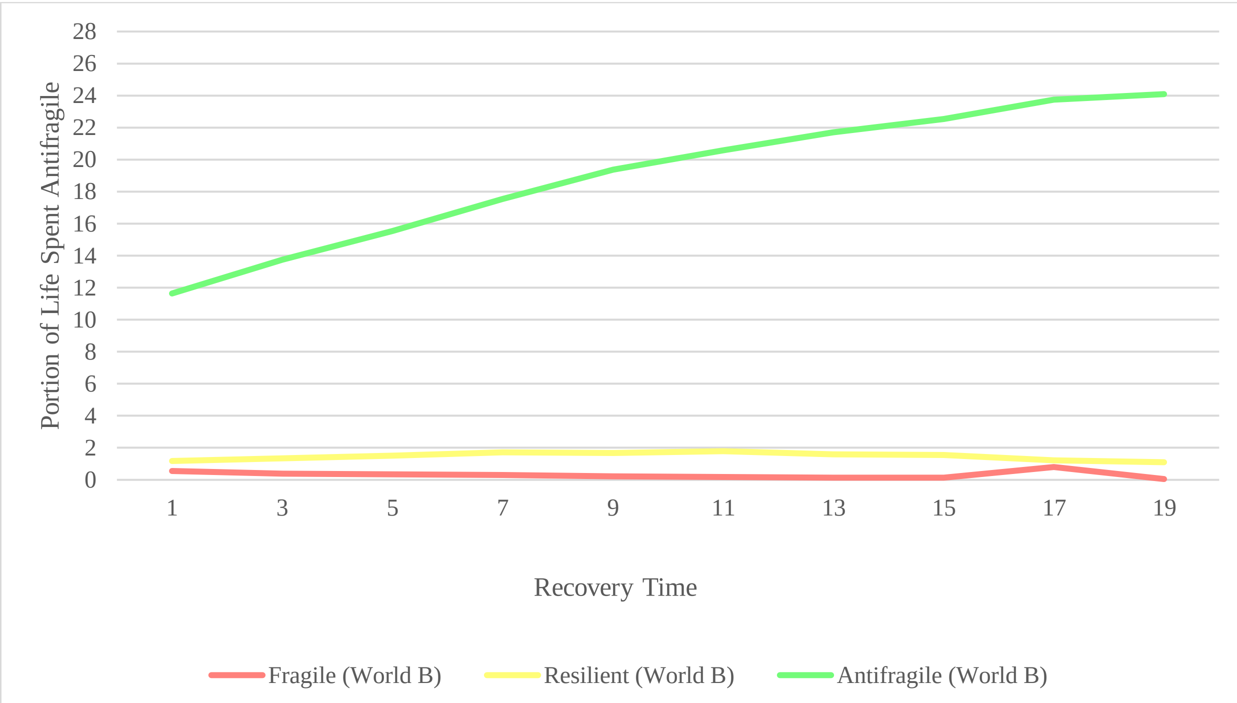


Initially fragile states and resilient states increase the average portion of their life spent antifragile with respect to an increase initial performance. Initially fragile states average portion of their life spent being antifragile increases from an average final performance value of 0 at the lowest initial performance value (1) to an average portion of life spent being antifragile value of 1.3 at the greatest initial performance value (19). Initially resilient states increase the portion of their life spent being antifragile from 0 when their initial performance value is 0 to 5.56 when their initial performance value is 19. Initially antifragile states differ with respect to their initially fragile and initially resilient state counterparts in terms of behavior. Initially antifragile states actually decrease their time spent being antifragile as initial performance increases from 30.97 when initial performance is at its lowest to 13.46 when initial performance is at its highest value (19).

The greatest point of divergence between initially resilient states and initially fragile states occurs at the highest initial performance value (19). The maximum point of divergence between antifragile states and resilient states also occurs at the lowest initial performance value (1). These are very important results because they highlight how high initial performance helps initially fragile or resilient states to become anti-fragile under some circumstances, an opportunity that they don't have if they die too soon.

Figure 32 below examines the impact of initial antifragility, resilience, and fragility on the state's average portion of life spent being antifragile relative to recovery time. The model runs reveal important non-linear interactions between the degree of initial state fragility / antifragility and recovery time in shaping the average portion of time the state spent being antifragile during its lifetime.

Figure 32: Impact of Initial Antifragility, Resilience, and Fragility on the Average Portion of Time Spent being Antifragile with Respect to Recovery Time (World B)



Initially fragile states decrease the average portion of their life spent antifragile with respect to an increase recovery time. Initially resilient states increase the portion of their life spent being antifragile until recovery time is 11. After that point, the average portion of life spent being antifragile begins to decrease again. Finally, initially antifragile states steadily increase the portion of time being antifragile as recovery time increases.

At the lowest recovery time (1), the portion of life spent being antifragile for initially fragile states is 0.55. At the highest recovery time (19), the portion of life spent being antifragile for initially fragile states is 0.05. At the lowest recovery time (1), the portion of life spent being antifragile for initially resilient states is 1.16 and is 1.1 at the highest value of recovery time (19).

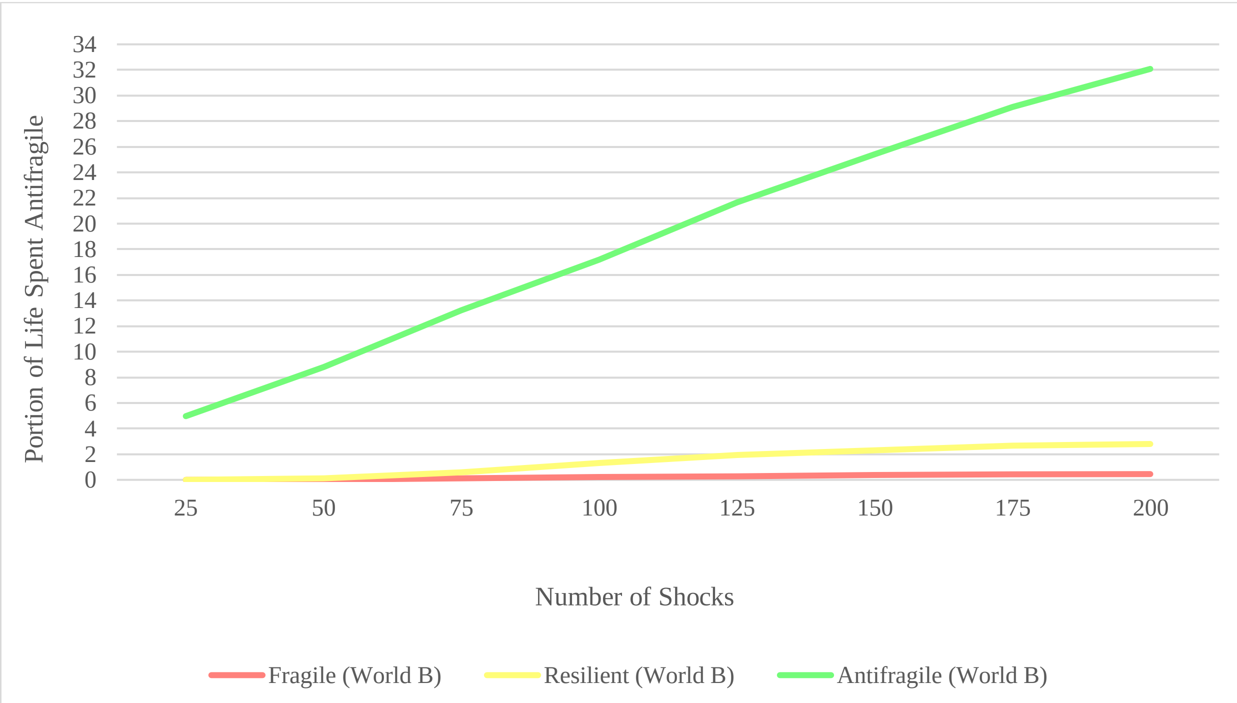
Initially antifragile states differ with respect to their initially fragile and initially resilient state counterparts in terms of behavior, as they consistently increase the portion of time spent being antifragile with an increase in recovery time. At the lowest recovery time value (1), the portion of time spent being antifragile is 11.64%. At the highest recovery time value (19), the portion of time spent being antifragile is 24.09%.

Again, the results reflect the modeling choice that while a state is recovering it is not forgetting; therefore, the antifragile states are gaining from longer recovery periods because they are able to maintain their antifragility and not forget as much as they might if they were not recovering.

The greatest point of divergence between initially resilient states and initially fragile states occurs at the when recovery time is 11. The maximum point of divergence between initially antifragile states and initially resilient states also occurs at maximum recovery time (19).

Figure 33 below examines the impact of initial antifragility, resilience, and fragility on the state's average portion of life spent being antifragile relative to the number of shocks in the environment. The model runs reveal important non-linear interactions between the degree of initial state fragility / antifragility and the number of shocks in the environment in shaping the average portion of time the state spent being antifragile during its lifetime.

Figure 33: Impact of Initial Antifragility, Resilience, and Fragility on the Average Portion of Time Spent being Antifragile with Respect to Number of Shocks (World B)



All three state types increase the average portion of their life spent antifragile with respect to an increase in exposure to shocks. With the lowest number of shocks in the environment (25), the portion of time spent being antifragile is 0 for initially fragile states. When the environment has the maximum number of shocks in the environment (200), the portion of time spent being antifragile is 0.45 for initially fragile states. With the lowest number of shocks in the environment (25), the portion of time spent being antifragile is 0 for initially resilient states. When the environment has the maximum number of shocks in the environment (200), the portion of time spent being antifragile is 2.8 for initially resilient states. Finally, with the lowest number of shocks in the environment (25), the portion of time spent being antifragile for initially antifragile states is 4.97. When the environment has the maximum number of shocks in the environment (200), the portion of time spent being antifragile is 32.08.

The greatest point of divergence between both initially resilient states and initially fragile states and initially resilient states and initially fragile states occurs at when the number of shocks in the environment is at its greatest value (200).

WORLD B ANALYSIS CONCLUSION

In conclusion, the World B experiments demonstrate that no matter what their initial state type, all states have the possibility to learn to become antifragile. The type of environment most capable of teaching a state to be antifragile (and helping the state remain antifragile) is one with lots of shocks since shocks are what prompts state learning of antifragility and prevents forgetting. Therefore, no matter what their initial type, final average performance is highest when there are more shocks because this allows states (no matter what their initial type) to become and to remain antifragile.

WORLD A AND WORLD B RESULTS IMPLICATIONS

With the results presented, it is important to understand the implications of the experimental results to both state antifragility and International Relations in both World A and World B. First and foremost, the results from World A provide evidence to suggest that that antifragility is important to state power and state survival, specifically in the model with respect to the dependent variable, life length.[136]

Specifically, the results from World A's experimental design provide evidence to suggest that increasing the number of shocks in the environment (or having a more chaotic world) does not have a significant impact on the life length of the antifragile state relative to the impact of

[136] At the core of the realist paradigm is a state's ability to survive in an anarchic world; thus, examining life length as a dependent variable makes sense as the concept of state antifragility is theoretically nested in the Realist school.

increasing the number of shocks for resilient and fragile states' life lengths. In World B, an increase in the number of shocks has an initially detrimental impact on the life length for the initially antifragile state; however, the results suggest that the initially antifragile state benefits from an increase in the number of shocks via a longer life length, reaffirming what we know to be true about antifragile entities from Taleb and Treverton (2015). That is, the antifragile gains from disorder. This is important to states as antifragility can help states overcome shocks in the international environment that are unpredictable but have severe consequences, or in some cases suggest that if states have awareness of antifragility that they might even design state structures such as governments and institutions to benefit from stress.

How and why initially antifragile states gain from disorder is primarily evidenced by the difference in the two experimental designs for World A in World B. That is, learning and forgetfulness have a role in the state's capacity to become antifragile, resilient, or fragile in World B. States that learn more than they forget have a greater capacity to become antifragile, and states that forget more than they learn have a decreased capacity to become antifragile.

Second, the results of the World B experiment are useful in that they provide evidence as to what types of worlds are best for maintaining antifragility. Examining all of the dependent variables across World B with respect to life length, states that possess a higher initial performance value, experience a moderate to large number of shocks, possess a higher learning ability and lower forgetfulness ability, and have a moderate recovery time are well positioned to maintain their antifragility. Understanding under what conditions states can best maintain their antifragility has strategic implications for states with regard to their foreign policy decisions. For example, states may be strategic about which foreign entanglements they wish to engage with by having knowledge of which stressors they might benefit from.

CONCLUSION

This chapter presented the results of the model experiments in Chapter 4. To summarize those experimental structures, the static model analysis in World A focused on providing insights into how antifragility is important for state survival and is a static model in which capacity is fixed: states neither learn to be antifragile nor forget and cease to be antifragile. That is, their *percent-learn* and *percent-forget* variables are set to 0, and the state simply runs into shocks and remains fixed as either fragile, resilient, or antifragile.

The dynamic model runs in World B examined what kind of world is going to be best for state survival and maintaining antifragility, and in this model state capacity does change: states can 'learn' to have a higher capacity and become (more) antifragile, and they can forget their existing capacity and become (more) fragile. That is, the agent's *percent-learn* and *percent-forget* variables are greater than 0. The structure of the experiments and the results of these experiments underscores the need for a simulation model to draw out how various factors in the model intersect and highlight different conditionalities, especially as it pertains to the ways in which states can 'learn' or 'forget' when it comes to their capacity to behave as antifragile states when confronted with shocks.

The results of the experiments yielded several nonlinear key results of numerous independent variables with respect to life length, initial performance, recovery time, and the number of shocks in the environment.

For example, in both World A and World B, an increase in recovery time results in a decrease for all state types, with an interesting observation in World B: antifragile states actually increase their life length in the recovery time range of 7 to 11. With respect to an increase in the number of shocks in the environment, all states experience a decrease in their life length, except for at the 75-shock value in World B. Here, all states begin to experience an increase in their life length with an increase in the number of shocks in the environment.

Additionally, the results from World B reveal that portion of time a state spends being antifragile increases with respect to an increase in recovery time; thus, states are not forgetting while they are recovering and are able to maintain their antifragility. A similar behavior is observed when examining an increase in the number of shocks in World B. The portion of time a state spends being antifragile increase with respect to an increase in the number of shocks, demonstrating that the how the antifragile gains from volatility (Taleb and Treverton, 2015).

The next two chapters present a series of case studies along with custom simulation runs of the model tuned to reflect various contexts in the real world in which antifragility can help enhance the explanatory power of state behavior within the historical events presented in the next two chapters.

CASE STUDY: THE IRAQ WAR

The two case studies presented in the next two chapters examine key issues in international studies through both the lens of the fragility to antifragility continuum and the results of the simulation model. Each case study is intentionally diverse, focusing on various contexts to showcase the applicability of antifragility to a variety of key issues in international relations. First, the Iraq War case study examines conflict between state and non-state actors. This case study was chosen for several reasons. It serves as a recent and historical example. Most reading this dissertation have been affected directly by both the September 11, 2001, terrorist attacks and subsequent war that followed. Whether directly as someone who served in this conflict or indirectly as someone who has known someone who lost their life during this conflict, this example touches most of us in some way or fashion.

Second, the notion that a non-state actor such as Al Qaeda could at one point in history be more antifragile than one of the most powerful nations in the world is contradictory to the mental models we hold as Americans. Mental models are an important component of international studies in that they help inform our world views including those related to our foreign policy beliefs, how those foreign policies are constructed, and by what governmental organizations they are executed. As such, the United States and most western nations have adopted the "bigger, faster, and more is better" mentality. In other words, if our military possesses more weapons on the battlefield, we can overcome our adversary. If our government spends more money to develop technology, the more expensive technology is somehow better than those that are less costly. Finally, if our armed forces have more weapons and spend more on those weapons, then our armed forces can overcome any adversary at any time. It is these mental models that were in direct contract with transnational terrorist organizations such as Al Qaeda, who simply

"MacGuyvers"[137] weapons with whatever resources are available to inflict maximum harm. It was these contrary mental models that clashed on the battlefields in Iraq.

Furthermore, and most importantly, the Iraq War (2003-2011) case study provides readers with an example that highlights a weakness of Realism in international relations. Recall that Realism posits that states are the single, most important actor in the international system. However, the Iraq War case study demonstrates that a transnational terrorist organization such as Al Qaeda that rendered the loss of countless lives and perpetuated an eight-year conflict is worthy of examination and consideration as an important international actor that can yield influence and power on a global scale.

As the results from the simulation model are presented from two perspectives. In the first run, the agent is the United States military, and the environmental conditions are those produced by Al Qaeda. This simulation run demonstrates that, though the United States had a lot of power at the time, with regard to non-state actors such as Al Qaeda, the United States was considered fragile. In the second run, the agent modeled as Al Qaeda in Iraq, and the environmental conditions are those produced by the United States military. As the simulation run reveals, Al Qaeda in Iraq begins with a large capacity, but their capacity degrades over time. So, for the first part of its history, it is antifragile, as it demonstrates by getting stronger as it hits shocks. However, by 2007 the United States is learning how to fight counterinsurgency, so it is no longer doing the sorts of shocks that the insurgency is antifragile with respect to (at least not so much) and they become fragile. Subsequently, Al Qaeda in Iraq degrades and weakens over a period of time.

[137] MacGyver was a popular television series that ran from 1985-1992 in which the protagonist, Angus MacGyver, is known for his improvisation and quick-thinking problem-solving skills to demonstrate inventive use of common items to employ countermeasures to thwart nefarious plots and schemes. As such, MacGyver refused to carry a gun and instead relied on non-traditional resources to apply countermeasures to problems. To "MacGyver" something implies that the individual "MacGyvering" possesses the same skills as Angus MacGyver.

The second case study focuses on the most recent tension between the United States and China in the Indo-Pacific, examining a real-time great power competition in the twenty-first century. This case study was selected primarily because of the author's experience working at the United States Indo-Pacific Command (USINDOPACOM) from 2019-2020 during which, USINDOPACOM became the priority theater for the Department of Defense. What is most critical about the Indo-Pacific region and China's role is how China is actively seeking to shape this region and fundamental consequences of the shape of the world order and subsequently the principles and values that will fashion this new world order. This matters to international relations scholars as we watch the dynamics of great power competition play out before our eyes and whose outcome is yet to be determined.

Most importantly, the two cases provide support for the key intuitions underlying the model and analysis. That is, the ability to effectively learn is an important component of antifragility. Finally, the case studies aim to build support for the key argument of the dissertation – that understanding whether states and other international actors are antifragile or not is important for understanding, interpreting, and effectively strategizing for future stressors in the international environment.

THE UNITED STATES WAR ON TERROR IN IRAQ

The Iraq War (2003-2011) and the failures to eliminate or even effectively contain Al Qaeda in Iraq over significant periods of time illustrate the ways in which counter-insurgency operations can end up rendering the enemy antifragile by radicalizing the population and building support for the insurgency. In the context of conflict, which regime is more fragile or antifragile matters a great deal. Fragile regimes fail and are lost.[138] Resilient regimes recover to

[138] Recall example in Chapter 2 on Roman Empire.

a state that was known prior to experiencing a shock; therefore, they have not benefited in the long run from their experience. The antifragile regime, however, is one in which the regime has benefited from some stressor or shock, and because of this benefit has an advantage over adversaries who have not gained this benefit (fragile or resilient regimes.)

The Iraq War (2003-2011) illustrates how attributes such as learning, decentralization, redundancy, and power conversion all played a critical role in the success of an unlikely "winner" and the consternation of an unlikely "loser."

Introduction to The Iraq War (2003-2011)

Perhaps the pre-immanent shock of the first years of the twenty-first century was the horrific terror attacks on September 11, 2001. The story of that event, both in terms of its antecedents and the wars that followed can be beneficially reexamined through the lens of antifragility. This is a tale of unequal adversaries, and one in which repeatedly the United States exercised superior power in ways that created new weaknesses, vulnerabilities, and challenges for itself, problems which its adversaries repeatedly exploited and took advantage of. This tale of fragility (U.S.) and antifragility (Al Qaeda and the Islamic State of Iraq and Syria) is punctuated by periods of learning and associated success.

The most recent War in Iraq (2003-2011) has drawn many comparisons and parallels to that of the Vietnam War in terms of its warfare tactics, length, and questionable success.[139] With the prior successes in Bosnia and Serbia in 1991, there was little reason to believe that the United States military would suffer any setback or defeat when locating and eradicating terrorists in Iraq and Afghanistan; yet, the Iraq War provided the United States with an exceptional example of diplomatic and military misalignment, or lack of strategy, that gave rise to the beginnings of an

[139] Nessen, Ron. "Iraq and Vietnam-Differences and Similarities." Brookings, March 21, 2008. https://www.brookings.edu/opinions/iraq-and-vietnam-differences-and-similarities/.

insurgency, which at the height of its power, resembled a nation-state and its institutions, notwithstanding the viscous bloodlust and arcane implementation of such governance.[140]

In 2013, the United States and coalition partners around the globe marked a grim and sobering ten-year anniversary. With an estimated 190,000 coalition and indigenous Iraqi citizens lives lost and the $2.2 trillion cost, the ten-year anniversary of the Iraq invasion was acknowledged by world leaders on March 19, 2013.[141] This date marked the day a United States-led coalition invaded Iraq with the goal of deposing the Saddam Hussein regime and rooting out weapons of mass destruction (WMD). The primary goal was "easily" achieved by standard measures of war. The Iraqi Army and Republican Guard were quickly dismantled, and in May 2003, a mere two months after the initial invasion, President George W. Bush, onboard the USS Abraham Lincoln, declared "Mission Accomplished", signifying to the world the strength and might of democracy, freedom, and fortitude of American capability. While victory achieved by the world's most powerful military forces against an ill-equipped and fractured opponent that was never truly reconstituted following its disastrous performance during the 1991 Gulf War, coupled with a decade of economic sanctions was not a shock, the resulting challenges that followed were certainly not as easily anticipated.

Caught flat footed, the United States military and political apparatus were flummoxed as to how a tribal and sectarian-based insurgency, lacking post-modern political, monetary, and technological resources, could capitalize on the power vacuum left by a leader reviled by its own people (outside of his tribe and Sunni-laden bureaucracy). Irrespective of the demonstrated illiteracy of U.S strategic and political goals and the inability to translate strategic victory into

[140] Hoffman, Bruce. "Insurgency and Counterinsurgency in Iraq." *Studies in Conflict & Terrorism* 29, no. 2 (June 24, 2006): 103–21. https://doi.org/10.1080/10576100500522173.
[141] Coelho, Courtney. "Iraq War: 190,000 Lives, $2.2 Trillion." New from Brown. Brown University, March 14, 2013. https://news.brown.edu/articles/2013/03/warcosts.

operational and tactical stability, insurgent elements were able to unhinge the most powerful military in modern history in ways that were eerily reminiscent of the Vietnam War. In other words, how could a non-state actor, such as Al-Qaeda in Iraq, Shia-backed Mahdi militia, or other regional terror groups be more antifragile than the United States military?

Setting The Stage: The Gulf War (1990-1991)

The United States and Iraq are no strangers to regional and international drama. Prior to its open engagement in armed conflict in 1991, the United States and Iraq were "allies" of sorts in the campaign to undermine Ayatollah Khomeini following his rise to power on the heels of the 1979 Iranian Revolution. During the subsequent eight-year war, the United States is alleged to have provided very sensitive intelligence to Iraq as early as 1982, as fears grew in Washington that Baghdad could be overrun by an Iranian offensive.[142] Although the United States was also rumored to have supplied Iran with U.S. weapons and spare parts through Israel as an intermediary, the "assistance" provided to Iraq cannot be discounted.

Following this period of "neutrality", the shock to the international order posed by Iraq and their rapid seizure of Kuwaiti oil fields and occupation of Kuwait City, caused alarm among the community of nations, especially those with oil interests in the region. The United States calculated and staked its claim that an unpunished Iraq could lead to regional instability. Seeking to suppress the randomness that would inevitably result from this instability, the international community was quick to condemn Saddam Hussein's invasion of Kuwait in 1990.

With international support from thirty-nine nations, the United States, led by then President H.W. Bush, launched the Gulf War to expel Iraq from Kuwait. By January 1991, the allied coalition against Iraq had reached a strength of 700,000 troops to the 300,000 Iraqi troops

[142] Hersh, Seymour M. "U.S. Secretly Gave Aid to Iraq Early in Its War Against Iran." The New York Times, January 26, 1992. https://www.nytimes.com/1992/01/26/world/us-secretly-gave-aid-to-iraq-early-in-its-war-against-iran.html.

occupying Kuwait.[143] Furthermore, the United Nations Security Council, invoked Chapter VII of the United Nations Charter and passed Resolution 678 which gave Iraq until January 15, 1991, to withdraw from Kuwait and empowered states to use all necessary means to force Iraq out of Kuwait after the deadline.

The Bush administration spent a substantial amount of time leading up to the Gulf War traveling the world to ensure that the United States received either economic backing, military backing, or both from a multitude of nations. Furthermore, the Bush administration knew there would need to be sufficient representation by Arab nations in this coalition in order to sell the prospect of war. As the Cold War began to dwindle, the United States was even able to garner the support of the Soviet Union for the United States led intervention in Kuwait. In the case of the Gulf War, the coalition of the willing was overwhelmingly supportive of the liberation of Kuwait. The sovereignty of Kuwait had been clearly violated by another nation for all the world to bear witness; thus, the decision to "be on the right side of history" was a seemingly easy one to make, and President Bush ensured that all nations a part of this coalition would have skin in the game.

The Gulf War (both Desert Shield and Desert Storm) lasted just shy of seven months and resulted in Iraqi forces being expelled from Kuwait and ultimately a coalition victory. Following the Gulf War, the United States and its allies executed a policy of containment on Saddam Hussein and his regime, comprising of economic sanctions by the United Nations Security Council, the enforcement of Iraqi no-fly zones, and ongoing inspections to ensure Iraq's compliance with the United Nations resolutions concerning Iraqi weapons of mass destruction.

[143] "Persian Gulf War." Britannica. Accessed 2017. https://www.britannica.com/event/Persian-Gulf-War.

The United States military, by all accounts, was well prepared and equipped to effectively engage the Iraqi military in the first Gulf War (1990-1991), and the Iraqi Armed Forces were unprepared for the power and resources of the United States military brought to bear and as a result, were rapidly driven out of Kuwait in a relatively short period of time. For the United States, the best example of applying the design principles of antifragility is during the first Iraq War (1990-1991). Themes of decentralization, building redundancy and overcompensation through a coalition effort, and ensuring everyone has skin in the game are seen throughout the campaign.

For example, the United States' thirty-nine-nation coalition followed one of Sterling's the six antifragile system design principles by building in redundancy and overcompensation (Sterling, 2013) through the amassing of an international coalition force. By all measures of traditional power (combat capability, the potential to conduct operations across the spectrum of actual war fighting, maintaining balanced combat, combat-support and combat-service-support capacity, range or distance at which operations can be conducted away from home territory, and ability to both surge for rapid intervention and to support enduring operational requirements over extended periods of time) the United States military alone could have successfully executed the first Gulf War.[144] However, the United States chose not to go at it alone, instead opting to work with coalition force. As a result, this choice rendered several advantages for the United States relative to antifragility.

First, choosing to garner a coalition rather than taking on the Iraqi Armed Force alone provided duplication of effort and resources to execute the job faster. As Table 26 shows, the

[144] Giegerich, Bastian, Nick Childs, and James Hackett. "The Three Types of Military Power and How to Measure Them." World Economic Forum, July 5, 2018. https://www.weforum.org/agenda/2018/07/the-three-types-of-military-power-and-how-to-measure-them/.

number of forces the United States brough to the Iraq War were increased by 50% when coalition forces were included in the campaign; thus, a layered system of sorts was introduced when developing a strength of force.

Table 26: Strength of Forces During the Gulf War (1990-1991)[145]

	United States	Coalition	Total
Peak Strength	541,000	251,000	795,000

However, support could also be quantified monetarily by the contributions each of those coalition members brought. Table 27 shows the major allied commitments to U.S. costs during the first Gulf War, again demonstrating a layered monetary system for funding the war.

Table 27: Major Allied Commitments to US Costs (US dollars in millions)[146]

	Initial Pledge	Second Pledge	Total Pledged
Saudi Arabia	3,339	13,500	16,839
Kuwait	2,506	13,500	16,006
United Arab Emirates	1,000	3,000	4,000
Japan	1,740	9,000	10,740
Germany	1,072	5,500	6,572
Korea	80	305	385
Other	3	17	20
Total	9,740	44,822	54,564

145 Freedman, Lawrence, and Efraim Karsh. *The Gulf Conflict, 1990-1991: Diplomacy and War in the New World Order*. Princeton, NJ: Princeton University Press, 1995.
146 Freedman, Lawrence, and Efraim Karsh. *The Gulf Conflict, 1990-1991: Diplomacy and War in the New World Order*.

Furthermore, having a coalition of forces facilitated an increase in the exchange of non-quantifiable entities such as information, skills, experience, materials, and opportunities for learning during the conflict. Finally, and most importantly, participating in a coalition ensured that all nations had some skin in the game, whether it be monetary skin in the game or assets. As Taleb writes,

> Systems must ensure that all participants have skin in the game-participants must face the consequences of their actions and ensure failure as well as enjoy success. This will ensure that each participating will be motivated to learn as rapidly as possible and not take unwarranted risks. Danger arises when a select few-especially those with an abundance of resources or power-are able to capture the upside for themselves while exposing others to downside risks of losses or harm. (Sterling, 2013)[147]

In the years following the conclusion of the Gulf War, historians began to analyze and judge the efforts leading to, during and after the war. In his Foreign Policy article, *The Gulf War in Retrospect*, Tom Mahnken refers to the Gulf War as the "high water mark of post-Cold War cooperation," and writes,

> Skilled diplomacy backed by a series of United Nations resolutions, allowed the Bush administration to build a broad-based coalition to oppose Iraq. While it was diverse, each of its members could agree upon the objective of ejecting Iraq from Kuwait. The coalition encompassed 39 countries that spanned every continent. It included not only the United States, leading regional powers, and our major allies, but also former members of the Warsaw Pact, such as Czechoslovakia, Hungary, and Poland, as well as traditionally neutral states, such as Sweden. The Soviet Union and China played an

[147] Sterling, Bruce. "Antifragile System Design Principles." Wired, April 17, 2013. https://www.wired.com/2013/04/antifragile-system-design-principles/.

important role not by blocking action against Iraq in the United States. Israel similarly aided the coalition by showing forbearance in the face of Iraqi missile attacks. (Mahnken, 2011)[148]

The Gulf War was considered the largest coalition of allied nations since World War II.[149] The decisive victory for U.S. and coalition forces also held symbolic value for the United States military. As Shane Storey, an Army historian said, “Vietnam hung over as this mark of shame that we had failed. When the U.S. defeated Saddam Hussein and Iraq in 1991, there was a sense of this huge weight lifted off the shoulders of the U.S. Army.”[150] Additionally, the United States military received the added benefit of an outpouring of support from the public during this time due to the positive media coverage.

In the end, the United States suffered a total of 238 fatalities while Iraq lost around 30,000.[151] However, the Gulf War was not without its flaws, flaws that would leave an indelible mark on another President Bush, twenty years later.

While some see the Gulf War as an example of decisive, agile warfare in which the United States and its allies were able to decisively execute an operation that lasted a mere forty-two days, others saw its results differently.[152] According to Tom Mahnken, despite the impressive accomplishments, the Gulf War was not the strategic masterpiece many made it out to be. While the coalition was successful at achieving its military objective of forcing Iraq out of Kuwait in a relatively short period of time, the Iraqi leader, Saddam Hussein, was still alive and defiantly remained in power. Not long after the conclusion of the war, Saddam continued to defy

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148 Mahnken, Tom. “The Gulf War in Retrospect.” Foreign Policy, January 20, 2011. https://foreignpolicy.com/2011/01/20/the-gulf-war-in-retrospect/.
149 Lacdan, Joseph. “Gulf War Veteran Reflects on Pivotal War That Changed Army, the Nation.” Army.mil, August 3, 2020. https://www.army.mil/article/237752/gulf_war_veteran_reflects_on_pivotal_war_that_changed_army_the_nation.
150 Lacdan, Joseph. “Gulf War Veteran Reflects on Pivotal War That Changed Army, the Nation.”
151 Lacdan, Joseph. “Gulf War Veteran Reflects on Pivotal War That Changed Army, the Nation.”
152 Lacdan, Joseph. “Gulf War Veteran Reflects on Pivotal War That Changed Army, the Nation.”

the United Nations by refusing to allow United Nations inspectors into his country to perform weapons inspections. Saddam even planned to reinvade Kuwait again in the mid 1990s. As Mahnken concludes,

> In ending the war unilaterally before Saddam had been chastened, the Bush administration condemned the United States to a long-term presence in the Gulf in an effort to contain Iraq. This presence, and the sanctions imposed on Iraq due to Saddam's recalcitrance, in the end served as a rallying cry for jihadists such as Osama bin Laden against the United States and its friends in the region. (Mahnken, 2011)[153]

The strategy of "get in and get out" during the first Iraq War (1990-1991) without the removal of Saddam Hussein would lay a foundation for the next entanglement in the Middle East in which the United States would prove to be less agile and demonstrate a lack of learning from the previous Iraq War. The unintended consequences of this foundation would leave the United States more fragile than its new adversary, Al Qaeda. Though Al Qaeda in Iraq (AQI) had not been conceived during the Gulf War period, its larger affiliate, Al Qaeda, had been founded by Osama bin Laden twenty years prior, in the 1980s as a logistical network to support Muslims fighting against the Soviet Union during the Afghan War.[154] It would not be until the 1990s that Al Qaeda would gain footing and evolve to become the world's deadliest transnational terrorist organization.

Post-Gulf War (1991-2003)

With Saddam Hussein still remaining in power, the harsh repression of Iraq's Kurdish population along with the majority Shiite Arabs continued. At the conclusion of the Gulf War,

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[153] Mahnken, Tom. "The Gulf War in Retrospect." Foreign Policy, January 20, 2011. https://foreignpolicy.com/2011/01/20/the-gulf-war-in-retrospect/.

[154] The Editors of Encyclopedia Britannica, Al-Qaeda Islamic Militant Organization Retrieved From: https://www.britannica.com/topic/al-Qaeda

the United States-enforced no-fly-zone established a safe haven located in northern Iraq that was off limits to Iraqi aircraft and patrolled by allied war planes in an attempt to stem the exodus of Kurds from Iraq. Furthermore, the United Nations implemented economic sanctions against Iraq in order to hinder progress of its arms programs, including the development of nuclear, biological, and chemical weapons.

Despite these sanctions, Saddam's regime was determined to continue its progress of amassing such weapons. The United Nations inspection program during the mid 1990s uncovered a variety of prescribed weapons and prohibited technology throughout Iraq. With continued interference with United Nations inspections, frustration within the international community led United States President Bill Clinton to order the bombing of several Iraqi military installations in 1998 in what became known as Operation Desert Fox.[155] In spite of the bombing by the Clinton Administration, Iraq remained defiant and continued to refuse to allow inspectors to reenter the country.

At the same time, an old "ally" to the United States that was involved in countering Soviet designs was now emerging as a new and grave threat. After the completion of the Soviet withdrawal from Afghanistan in February 1989, Osama bin Laden returned home to Saudi Arabia, cast as a victor against the mighty Red Army and hero among the "Arab-Afghans" he sponsored. Despite his reputation, he remained a concern for his country of origin.

> While back home, he lobbied Saudi officials not to host U.S. combat troops to defend Saudi Arabia against an Iraq invasion, arguing instead for the raising of a "mujahedin" army to oust Iraq from Kuwait. His idea was rebuffed by Saudi leadership as impractical, causing bin Laden's falling out with the royal family, and 500,000 U.S. troops deployed

[155] "Operation Desert Fox." Defense.gov. Accessed 2021. https://archive.defense.gov/specials/desert_fox/.

> to Saudi Arabia to oust Iraqi forces from Kuwait in "Operation Desert Storm (January 16-February 28, 1991). About 6, 000 U.S. forces mainly, the Air Force, remained in the Kingdom during 1991-2003 to conduct operations to contain Iraq. Although the post-1991 U.S. force in Saudi Arabia was relatively small and confined to Saudi military facilities, bin Laden and his followers painted the U.S. forces as occupiers of sacred Islamic ground and the Saudi royal family as a facilitator of that 'occupation'. (Katzman, 2005)[156]

After his experience with the Saudi royal family, bin Laden moved to Sudan to host and train Al Qaeda militants; however, this time, their target would not be the Soviets found in the hills of Afghanistan, but rather the United States and its interests both domestically and abroad. With his strategist and closest ally, Dr. Ayman al-Zawahiri by his side, Osama bin Laden transformed Al Qaeda into a global threat to U.S. national security, culminating in the September 11, 2001, attacks. To support this coalition, Osama Bin Laden began to garner resources and financial support through undetected channels to the West. According to the 9/11 Commission Report, Bin Laden expanded Al Qaeda during this time all the way to the United States itself. His expansionism through the building of alliances extended to the Farouq mosque in Brooklyn, New York. Other cities with branches included Atlanta, Boston, Chicago, Pittsburg, and Tucson where American Muslims were recruited to fight in Afghanistan and participate in terrorist activities in the United States in the early 1990s.[157]

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[156] U.S. Library of Congress. Congressional Research Service. *Al Qaeda: Profile and Threat Assessment* by Kenneth Katzman RL33038

[157] Kean, Thomas H, Lee H. Hamilton, and Richard Ben-Veniste. Rep. *The 9/11 Commission Report*. Washington, D.C.: The United States Commission on Terrorist Attacks Upon the United States, 2004.

However, in order to evaluate the success of the Al Qaeda, one must first understand what Al Qaeda intended to achieve. According to Professor Juan Cole's 2004 piece in the George Mason History News Network,

> From the point of view of al-Qaeda, the Muslim world can and should be united into a single country. They believe that it once had this political unity, under the early caliphs. From al-Qaeda's point of view, the political unity of the Muslim world was deliberately destroyed by a one-two punch. First, Western colonial powers invaded Muslim lands and detached them from the Ottoman Empire or other Muslim states…Second, they formed these colonies into Western-style nation-states, often small and weak ones, so that the divisive effects of colonial conquests have lasted. For al-Qaeda to succeed, it must overthrow individual nation-states in the Middle East, most of them colonial creations, and unite them into a single, pan-Islamic state. (Cole, 2004)[158]

Part of the execution of this succinct strategy was to work from outside in. That is, deal with Western nations, namely the United States, abroad and then once success is achieved, focus on the near states. Table 28 provides a summary of this strategy.

[158] Benko, Ralph. "9/11: The Fall of Empire And The Rise of The Empire of Liberty." Forbes, September 11, 2015. https://www.forbes.com/sites/ralphbenko/2015/09/11/911-the-fall-of-empire-and-the-rise-of-the-empire-of-liberty/?sh=34df7160298b.

Table 28: How Denial and Deception Fit into Al Qaeda's Overall Policy and Strategy.[159]

<table>
<tr><td colspan="4">Al Qaeda's Policy: Establish regimes sympathetic to Al Qaeda's interpretation of Islam. The ultimate goal is to re-establish a Caliphate.</td></tr>
<tr><td colspan="4">Al Qaeda's Grand Strategy: Use all necessary means to influence "infidel" and "apostate" countries to change their foreign policies in such a way to allow Al Qaeda and its affiliates the opportunity to achieve the policy of establishing a Caliphate. Elements of this strategy include the use of violence, the media, charismatic leaders, financial systems, etc.</td></tr>
<tr><td colspan="4">Deception and Denial support this strategy in the following areas:</td></tr>
<tr><td>Institutionalized training</td><td>Travel</td><td>Financing</td><td>Communications</td></tr>
<tr><td colspan="2">CI Denial Strategies</td><td colspan="2">Deceiving Islam</td></tr>
</table>

Aided by Osama bin Laden's reputation from his time in Afghanistan and cult of personality, Al Qaeda was able to initiate a worldwide global fundraising architecture that went largely undetected because it was coupled with Islamic charity organizations that supported jihadist causes.[160] As Deven D. Jessee's paper Tactical Means, *Strategic Ends: Al Qaeda's Use of Denial and Deception* paper outlines,

> Al Qaeda's most well-known financial deception before the 9/11 attacks related to charities. In some instances, Al Qaeda siphoned money from entirely corrupt charities or NGOs.; in others, it infiltrated the organizations with operatives who then diverted funds back to Al Qaeda. In illustration, the Wafa Charitable Foundation was an entirely corrupt charity that raised funds for supposedly good purposes but then diverted them to Al Qaeda. Further Enaam Arnaout pled guilty to taking money from the Benevolence International Foundation, a legitimate charity, and funneling it to jihad fighters while

[159] Jessee, Devin D. "Tactical Means, Strategic Ends: Al Qaeda's Use of Denial and Deception." *Terrorism and Political Violence* 18, no. 3 (January 25, 2007): 367–88. https://doi.org/10.1080/09546550600751941.
[160] Koker, Tolga and Yordan, Carlos L., Microfinancing Terrorism: A Study in Al Qaeda Financing Strategy (August 1, 2008). State of Corruption, State of Chaos: The Terror of Political Malfeasance, M. Cox, ed., pp. 167-82, 2008, https://ssrn.com/abstract=1287241

deceiving donors by telling them that it was being used for humanitarian purposes. (Jessee, 2006)[161]

Most notably, however, is that Al Qaeda did not wait for opportunities of learning, or shocks. They created their own shocks, serving as precursors to the September 11, 2001, attacks. Each of these attacks can be viewed as a local, "dry run" for Al Qaeda to both execute its newfound skills and subsequently learn from them. Furthermore, each of these local failures serves as an opportunity for Al Qaeda to learn and make minor adjustments to its strategies on a local level rather than risk the potential of grand failure at the systemic level (Sterling, 2015). Table 29 outlines five previous attacks against the United States that are widely attributed to Al Qaeda.

Table 29: Pre-September 11, 2001, Attacks Against the United States Attributed to Al Qaeda[162]

Date	**Location and Event**
February 1993	**World Trade Center, New York, USA**. Central figures in this bombing included key bomb maker Ramzi ahmad Yusuf, suggesting Al Qaeda involvement.
October 1993	**Mogadishu, Somalia.** Al Qaeda claimed responsibility for arming Somali factions who battled U.S. forces and killed 18 U.S. special operations forces
June 1996	**Saudi Arabia**. Bombing of Khobar Towers complex near Dhahran, Saudi Arabia. Nineteen U.S. airmen were killed.
August 1998	**Kenya and Tanzania.** Al Qaeda was responsible for the bombings of two U.S. embassies in Kenya and Tanzania, which killed about 300.
October 2000	**Aden, Yemen.** Al Qaeda attacked the U.S.S. Cole in a suicide bombing while the Cole was docked in harbor. Seventeen sailors were killed.

[161] Devin D. Jessee, Tactical Means, Strategic Ends: Al Qaeda's Use of Denial and Deception, Terrorism and Political Violence, Retrieved From: https://www.peacepalacelibrary.nl/ebooks/files/FTPV_A_175157_P.pdf
[162] U.S. Library of Congress. Congressional Research Service. *Al Qaeda: Profile and Threat Assessment* by Kenneth Katzman RL33038

Though incomparable to the number of shocks (conflicts) the United States had participated in, the type of shock here seems to matter more than the quantity. That is, Al Qaeda rehearsed a series of attacks involved bombings. The only recent history the United States had in combating guerilla type warfare against insurgents had been in the jungles of Vietnam, which has been viewed by many as unwinnable and a failure (Merom, 2003)[163].

Another way of viewing Al Qaeda's precursor attacks is through the Cynefin model, specifically in the complex domain representing the "unknown unknowns" of the world. Recall in this domain that cause and effect can only be deduced in retrospect, and there are no right answers. In this domain, experiments can be conducted that are safe to fail. In this quadrant of the world, the framework recommends "probe-sense-respond". These systems are "impervious to a reductionist, take-it-apart-and-see-how-it-works approach, because your very actions change the situation in unpredictable ways."[164] In order to ensure success abroad, the attacks carried out by Al Qaeda during the interim period between the end of the Gulf War and September 11, 2001 can be viewed as Al Qaeda's way of injecting shocks into the international system for the purpose of learning and to help cultivate agility for future endeavors. That is, Al Qaeda used this period to probe the system in order to learn from it.

By doing so, Al Qaeda first learned what responses each attack would evoke from the West. With each success, failure, and nonresponse by the United States, Al Qaeda enhanced their bomb making techniques, enhanced concealment methods, amassed resources for future operations, and reaffirmed their resolve. Second, each attack, no matter how small or large, helped Al Qaeda become more agile. That is, with each attack they were better able to sense,

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[163] Merom, Gil. *How Democracies Lose Small Wars: State, Society, and the Failures of France in Algeria, Israel in Lebanon, and the United States in Vietnam*. Cambridge, UK: Cambridge University Press, 2003.
[164] Stewart, Thomas A. "How to Think with Your Gut." *Business 2.0*, November 2002.

identify, and exploit Western vulnerabilities successfully so they could remain undetected and able to successfully infiltrate Western democracies through the establishment of operational cells. They explored various environments in which to test their strategies of attack whether land based as in the 1993 World Trade Center attacks or by sea in the bombing of the U.S.S. Cole in Yemen in 2000.

All of this learning and experience would culminate on the morning of September 11, 2001, when four passenger airliners bound for California were hijacked by nineteen Al Qaeda terrorists. American Airlines Flight 11 and American Airlines Flight 175 crashed into the North and South towers of the World Trade Center complex in Manhattan, New York. A third plane, American Airlines Flight 77, crashed into the Pentagon in Virginia, and a fourth flight, United Airlines Flight 93, was initially headed toward Washington, D.C. but crashed into a field in Shanksville, Pennsylvania after passengers thwarted the attack. The attacks resulted in 2,977 fatalities, over 25,000 injuries, and substantial long-term health issues for those who survived. In addition, over $10 billion in infrastructure and property damage occurred. As a result, the terrorist attack on September 11, 2001, is the single deadliest terrorist attack in history.

In hindsight, Al Qaeda’s complex operation on September 11, 2001, can viewed as the high-water mark of learning Al Qaeda underwent during the post-Gulf War period. After the attacks, United States intelligence agencies learned that each of the hijackers of the September 11, 2001, attacks spent an extensive amount of time and resources on how to commit passport and visa fraud to gain entry into the United States undetected. Moreover, it was revealed that when choosing means of travel, many of the hijackers traveled first class on both their casing flights and during the actual hijackings as the benefit of doing so was such that they received less scrutiny at the security checkpoints in the airports.[165] The development of and use of code in Al Qaeda's communications regarding operations highlights the depth and breadth of their learning experience. The Al Qaeda training manual explicitly instructs operatives to "converse on telephone using special code to ensure that he [the operative] does not attract attention.[166]

In examining the results from the simulation model, it can be said that Al Qaeda was operating in World B, in which the increase of shocks in the environment and increase in learning led to a high final performance.

September 11, 2001-March 19, 2003

After the attacks of September 11, 2001, the Bush Administration's national security team actively debated an invasion of Iraq. During the January 2002 State of the Union address, President Bush declared Iraq part of the Axis of Evil which included some of the most dangerous regimes in the world at that time. Throughout this time, President George W. Bush argued that Iraq's alleged continued possession and manufacturing of weapons of mass destruction along with its support for terrorist groups such as Al Qaeda, left the United States vulnerable to new attacks; thus, the disarmament of Iraq became a priority for the United States. The United Nations Security Council Resolution 1441 demanded that Iraq readmit United Nations inspectors and that it complies with all previous resolutions. Whether or not Iraq complied with the inspections remains subject to speculation. President George Bush and Prime Minister Tony Blair believed that Iraq was continuing to hinder inspections, while other world leaders such as France's President Jacques Chirac and German Chancellor Gehard Schröder believed there was evidence of increased cooperation from Iraq with respect to the United Nations inspections.

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[165] Jessee, Devin D. "Tactical Means, Strategic Ends: Al Qaeda's Use of Denial and Deception." *Terrorism and Political Violence* 18, no. 3 (January 25, 2007): 367–88. https://doi.org/10.1080/09546550600751941.

[166] Jessee, Devin D. "Tactical Means, Strategic Ends: Al Qaeda's Use of Denial and Deception."

Unlike the clarity of the situation in Iraq during the Gulf War, nations would have to pause for concern as to whether or not linking Sadaam Hussein with the terror attacks of September 11, 2001. Time and effort would not be given to convince another coalition of the willing to provide monetary and military support to invade Iraq again; thus, the United States centralized their efforts in the War on Terror early on. President George W. Bush failed to develop layered systems as his father had during the Gulf War.

The United States strategy to invade Iraq was heavily based on the notion of preemption. The terror attacks of September 11, 2001 had left the United States reeling, unsure where or when another attack might take place. As a result, the seeming randomness of these attacks had to be suppressed immediately and with great force. Under such conditions of societal and political uncertainty, President Bush energized his notion of preemptive attack on would-be attackers, an approach that would reshape American military doctrine and employment for a generation. Under this philosophy, the United States would never again be caught by surprise on their own soil. Rather, the fight would be taken abroad to prevent such atrocities. Bounded by these fears, the Bush Administration relied on intelligence that weapons of mass destruction amassed by Sadaam Hussein's regime, including nuclear weapons, would serve as the basis for invasion.

On March 17, 2003, President Bush delivered a televised address to the world, in which he summarized the events of the past few months between the United States and Iraq. In his speech, he made one simple demand. Saddam Hussein would vacate his office and leave Iraq within two days or else the United States would invade. Two days later on March 19, 2003, President Bush addressed the world in a second televised announcement that the United States had invaded Iraq with no strategy other than to root out terrorists wherever they reside.

The Iraq Invasion (2003)

The United States military entered Iraq with an underwhelming number of troops. General Shinseki, the then Army Chief of Staff, originally requested 500,000 troops for the invasion, and even testified to the United States Senate Committee on Armed Services that "several hundred thousand" troops would be required for operations in Iraq.[167] General Shinseki's request was denied, and he was only given 100,000 troops by Secretary of Defense Rumsfeld.

It was not long into the invasion before Saddam Hussein was captured in Operation Red Dawn on December 13, 2003. Subsequently, the Iraqi army was quickly dismantled, and the process of de-Baathification began, led by Paul Bremer. Those that once saw themselves as powerful ruling elites found themselves on other side of fortune and were suddenly ousted from power with no work and no status. A short two months later on May 1, 2003, President Bush stood onboard the USS Lincoln to announce victory in the war on Iraq.

Unlike the consent reached in the Persian Gulf War, no broad coalition was assembled to remove Saddam and his Baath party from power. Many in the Middle East saw the United States as a new brand of anti-Arab and anti-Islamic imperialism, and most Arab leaders decried the occupation of a fellow Arab country by foreign troops. The strategy was now forced to transition to one that would insert and transition the Iraqi government to that of a pro-western government. Whether this required immediate retreat from Iraq, or an established long-term presence was the subject of much debate within the United States government and military. As Michael O'Hanlon writes,

[167] Gibney, Frank. "The General Who Got It Right on Iraq." The Los Angeles Times, December 26, 2004. https://www.latimes.com/archives/la-xpm-2004-dec-26-op-shinseki26-story.html.

> The post-invasion phase of the Iraq mission has been the least-well planned American military mission since Somalia in 1993, if not Lebanon in 1983, and its consequences for the nation have been far worse than any set of military mistakes since Vietnam. The U.S. armed forces simply were not prepared for the core task that the United States needed to perform when it destroyed Iraq's existing government-to provide security, always the first responsibility of any sovereign government or occupier. (O'Hanlon, 2005) [168]

The invasion of Iraq in 2003 by the United States brought to the fore major weaknesses of the United States, namely strategy, learning, and agility. The strategy of "rooting out terrorists wherever they live" to removing Sadaam Hussein from power to establishing an interim, pro-Western government in Iraq was amorphous and ill-conceived. As the subsequent sections will show, the fight would morph form a battle between conventional armies to a complex entanglement with multiple militias, factions, and insurgencies. The focus would shift from countering traditional military forces to countering an insurgency. The result would expose the United States' lack of strategy to address the power vacuum it had left in Iraq's government by deposing Sadaam Hussein and the lack of strategy it had to both secure and rebuild a war-torn Iraq.

Furthermore, the initial invasion of Iraq highlighted the United States' forgetfulness of the lessons of the Vietnam War. As Charles Sladdin writes,

> Perhaps the most observable lesson the US failed to learn from Vietnam is the necessity for the right motivations to intervene in conflict, as well as the necessity of a structured strategy and clear goals. US reasoning for intervening in Vietnam was clear, yet this does not detract from the inherent lack of sustainability in the perceived motives for doing so.

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[168] O'Hanlan, Michael E. "Iraq Without a Plan." Brookings, January 1, 2005. https://www.brookings.edu/articles/iraq-without-a-plan/.

Under the doctrine of containment, the goal was to prevent the spread of communism by preventing the failure of the guardian to Central Asia, South Vietnam (a policy enshrined in 'domino theory') (Powers, 1969, p.855). The US's obsession with this doctrine and its stalwart determination to prevent the spread of this evil ideology led the Americans 'deeper and deeper into tragedy" (O'Malley, n.d.) in Southeast Asia.[169]

To compound this forgetfulness, the United States was also unable to quickly pivot from its tone deaf "strategy" to one that that that was able to sense forthcoming shift in adversaries, adapt, and then learn from it. In other words, agility was absent.

The 2004 Pivot: A Formal Insurgency

United States-led coalition forces found themselves in a precarious situation in 2004. After the initial invasion of Iraq in 2003, the successful collapse of the Ba'athist government and the capture of Saddam Hussein led to an unintended power vacuum that provided an accelerant to widespread sectarian violence between the Sunni minority and the long-marginalized Shi'a in Iraq. Although the first and primary goal of regime change was achieved relatively quickly, the second and more controversial goal of identifying and dismantling Saddam's weapons of mass destruction was just as swiftly plagued by shock and scandal. In January 2004, David Kay, the United States' Central Intelligence Agency's former chief weapons inspector, revealed that American intelligence agencies failed to recognize that Iraq had all but abandoned its efforts to produce large quantities of chemical or biological weapons since 1991. With one of the central justifications of invasion achieved and the other exposed and discredited, the year 2004 represented a further downward spiral for the United States-led coalition.

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[169] Sladdin, Charles. "Has the US Learned from Its Experience in the Vietnam War?" *E-International Relations,* February 21, 2020, 2021. https://doi.org/https://www.e-ir.info/2020/02/21/has-the-us-learned-from-its-experience-in-the-vietnam-war/.

Designated the deadliest year of the Iraq War, 2004 news headlines were dominated by stories of suicide car bombers, improvised explosive devices (IEDs), rocket propelled grenades (RPGs), mortars, missiles, and sniper attacks against coalition forces, and while the volume of violence increased, it was high-profile incidents such as the scandal at Abu Ghraib prison and the brutal murder of four Blackwater USA private security employees that gripped attention and shocked moral consciousness.

On March 31, Scott Helvenston, Jerry Zovko, Wesley Batalona and Mike Teague of Blackwater USA were horrifically murdered by Iraqi insurgents. Their bodies were publicly beaten, burned, drug through the streets of Fallujah and hung from a bridge over the Euphrates River.[170] Photos of the hangings with Iraqi insurgents celebrating were broadcast throughout the internet and 24-hour news channels, leaving an indelible mark on the tone of the war and would later become the impetus for the memorable April 2004 First Battle of Fallujah that would draw heavy global attention and criticism for its high civilian casualty rate. The largest combat mission since the declaration of the end of major hostilities in Iraq, the First Battle of Fallujah marked a turning point in public perception of the ongoing conflict because insurgents rather than Saddam loyalists were seen as the chief opponents of U.S. forces. At this point, the appeal of Al Qaeda in Iraq increased, such that Al Qaeda gained additional communication networks within the local communities. This, in turn, allowed for Al Qaeda to gain early detection on movement of U.S. forces in areas like Fallujah, and thus enhancing the organization's agility during this period, but who were the Sunni insurgents who reshaped the Iraq War overnight?

Under Saddam Hussein's regime, the Sunnis, though the minority, were insulated and protected by Saddam Hussein, a Sunni himself. With the invasion of Iraq and ultimate removal

[170] Crichton, Kyle, Gina Lamb, and Rogene Fisher Jacquette. "Timeline of Major Events in the Iraq War." The New York Times, 2013. https://archive.nytimes.com/www.nytimes.com/interactive/2010/08/31/world/middleeast/20100831-Iraq-Timeline.html.

of the ruling Ba'athist party, the Sunnis found themselves insulated one moment and facing an uncertain, unattractive future the next. Seeing the United States-led coalition forces as responsible for this social realignment, the Sunni insurgency quickly grew in strength through the attraction of religious radicals, foreign fighters, and common Iraqis angered by foreign occupation.

Culturally inclined to believe in conspiracies about the American troops, including the belief by some that Iraq was being invaded by Israeli troops who came to overthrow Iraq, the Sunni insurgency excelled at fabricating and disseminating propaganda about the nature of conflict and occupation. This psychological warfare played a significant role in the unification and success of the Sunni insurgency. During this time, there was an explosive growth in the distribution of media designed to discredit the foreign forces invading Iraq while simultaneously bolstering support for the underground resistance. One could not help but turn on the news to find evidence of this growth through the videos of journalists such as Daniel Pearl or James Foley along with British journalist Steven Sotloff forced to profess beliefs in an extremist ideology on camera before being beheaded for the rest of the world to bear witness.[171]

The success of the Iraqi Sunni insurgency was alluring, attracting foreign fighters from around the Middle East. Among those who joined forces with this insurgency were other radical groups including Al Qaeda in Iraq, led by Abu Musab al-Zarqawi, the Jordanian who had earned his stripes in Afghanistan as a low-level commander in Bin Laden's Al Qaeda. By 2004, the Central Intelligence Agency estimated that there were around 1,300 foreign fighters in Iraq linked to the insurgency. Later that same year, the numbers of foreign fighters entering Iraq were believed to be 150-200 per month, joining an estimated 12,000 to 20,000-member

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[171] Carter, Chelsea J. "Video Shows ISIS Beheading U.S. Journalist James Foley." CNN, August 20, 2014. https://www.cnn.com/2014/08/19/world/meast/isis-james-foley/index.html.

insurgency.[172] These factors, the influx of foreign fighters, graphic propaganda, and the on-going high casualties of U.S. military personnel and Iraqi civilians, signaled the to the American public that Iraq had now become ground zero in the fight against transnational Islamic terrorism, one that began in response to the attacks of 9/11. By September 2004, the number of United States troops killed in Iraq reached a grim milestone with 1,000 United States service members killed. That figure would double in just one year.

With little understanding and learning of Sunni disenfranchisement, the United States and coalition forces handed over sovereignty of Iraq to the interim Iraqi government on June 28, 2004.[173] The newly formed government, headed by Prime Minister Maliki, a Shi'ite, did little to include or ease the fears of persecution of the Sunni minority. With the transition of power, the Sunni minority, again, found themselves sidelined from national politics.

With insurgents controlling important parts of central Iraq, it became unclear when American and Iraqi forces would be able to secure those areas, if at all. [174] With support for the Iraq War waning at home and a loss of the United States' credibility abroad, concerns began to develop over the justification of the invasion and the nature of this emerging enemy. By the end of 2004, the Sunni insurgency and resultant chaos throughout the country had morphed and replaced the conventional Iraqi Army and Saddam loyalists as the primary threat to stability and security without wavering from their initial strategy. Now, however, they would have increased resources to execute this strategy. From 2004 forward, United States military forces would find themselves occupied fully in combating an ever expanding and mutating insurgency, one that

[172] McCrystal, Stanley. *My Share of the Task: A Memoir*. New York, NY: the Penguin Group, 2014.
[173] "Operation Iraqi Freedom and Operation New Dawn Fast Facts." CNN, February 24, 2021. https://www.cnn.com/2013/10/30/world/meast/operation-iraqi-freedom-and-operation-new-dawn-fast-facts/.
[174] Crichton, Kyle, Gina Lamb, and Rogene Fisher Jacquette. "Timeline of Major Events in the Iraq War." The New York Times, 2013. https://archive.nytimes.com/www.nytimes.com/interactive/2010/08/31/world/middleeast/20100831-Iraq-Timeline.html.

relied on the marginalization of the Sunni minority to provide a safe haven and the human terrain from which to operate.

The Sunni-backed insurgency, which had found its footing fully by 2004, was led by the Zarqawi's Al Qaeda in Iraq (AQI), a "franchise" of the parent organization headquartered in the hinterlands of Pakistan and still under the command of Bin Laden and his deputy, Ayman al-Zawahiri. As a franchise in name only, Zarqawi's program was divergent from Al Qaeda Central from the beginning, choosing to focus much of its energy and resources to fueling sectarian violence against the Shia population, something that traditional Al Qaeda consciously avoided. Furthermore, Zarqawi's campaign design relied heavily on the support of rural Iraqis, especially in Anbar Province. With a failed national government, groups like AQI found themselves in the business of governing large areas, a prospect that was certainly not preplanned.

In its aim to confront the United States specifically, AQI began to shift its strategy slightly as it "sought to draw the United States into a sectarian civil war by attacking Shias and their holy sites to provoke them to retaliate against Sunni civilians."[175] Not only did this confound the United States' efforts to stabilize the country, but also made political efforts at forming and fostering a legitimate Iraqi government exponentially more difficult. Danger and violence usually begat more danger and violence, leading to an increase in the United States military presence in the region as part of President Bush's surge strategy in 2006. Coupled with this increase of forces was the key push toward gaining support from tribal leaders throughout western Iraq, given the politically keen name of the "Anbar Awakening." This effort sought to exacerbate the divide growing between the Sunni insurgency and the civilian population forced

[175] Laub, Zachary. "The Islamic State." Council on Foreign Affairs, August 10, 2016. https://www.cfr.org/backgrounder/islamic-state.

to succumb to a relatively foreign and unusual brand (by Iraqi standards) of Islamic fundamentalism.

Though not anticipating have to govern large areas, AQI was able to rapidly adapt and shift their strategy, something the United States military was unable to do until 2006; however, under the leadership of General Petraeus, the United States would slowly recalibrate their efforts against the Sunni insurgency.

The 2007 Iraqi Sunni "Awakening" Movement and U.S Operations Troop Surge

According to Kenneth Katzman in a report to the United States Congress,

> In January 2007, President Bush articulated a new counter-insurgency strategy developed by Gen. Petraeus and others, based on assessments within the Administration and outside, that U.S. policy was failing to produce stability. The deterioration in the previous U.S. strategy was attributed, in part, to the burgeoning sectarian violence that AQ-I had helped set off. The cornerstone of the new strategy was to increase the number of U.S. troops in Baghdad and in Anbar Province in order to be able to protect the civilian population rather than conduct combat operations against militants. The U.S. "troop surge" reached full strength in June 2007. (Katzman, 2008)[176]

The U.S. surge in Iraq, and the development of counterinsurgency doctrine by Petraeus prior to his appointment to lead the war effort, marked a moment of learning and recalibration for the United States war effort. For a time, this shifted the U.S. away from strategies (e.g., staying in large bases and focusing on killing terrorists) which seemed to render the insurgents antifragile. Prior to the surge, U.S. troops were primarily concentrated in large bases isolated

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[176] U.S. Library of Congress. Congressional Research Service. *Al-Qaeda in Iraq: Assessment and Outside Links* by Kenneth Katzman RL32217

from the Iraqi population. A focus on pursuit of militants that generated collateral damage increased risks. Ineffective propaganda measures facilitated insurgent gains.

The revised strategy worked to separate insurgents from the population through a variety of means including putting Sunni militias such as the "Sons of Iraq" on the U.S. payroll. Better integration of soft and hard power elements attempted to increase the degree to which the U.S. was able to effectively convert power. As a result, and for a time, the AQI insurgency was brought more under control; however, the resolve of the AQI in surgency was stronger than ever and a new "head" of the terrorist hydra was emerging.

MODEL VALIDATION: THE UNITED STATES

Examining the case study of the Iraq War from 2003-2010, parameters from the case study were translated into the model to represent the internal conditions for the United States during this time (Table 30). Additionally, environmental conditions in modeled are those produced by Al Qaeda (Table 32).

Table 30: Agent Initialization Conditions (United States)

Variable	**Parameter Value(s)**
Performance	32
Capacity	1
Agent Type	Fragile
Percent-Learn	0.06
Percent-Forget	0.01
Recovery Time	17

Table 31: Environment Initialization Conditions

Variable	**Parameter Value(s)**
Gamma Mean	1
Gamma Variance	1
Number of Shocks	350

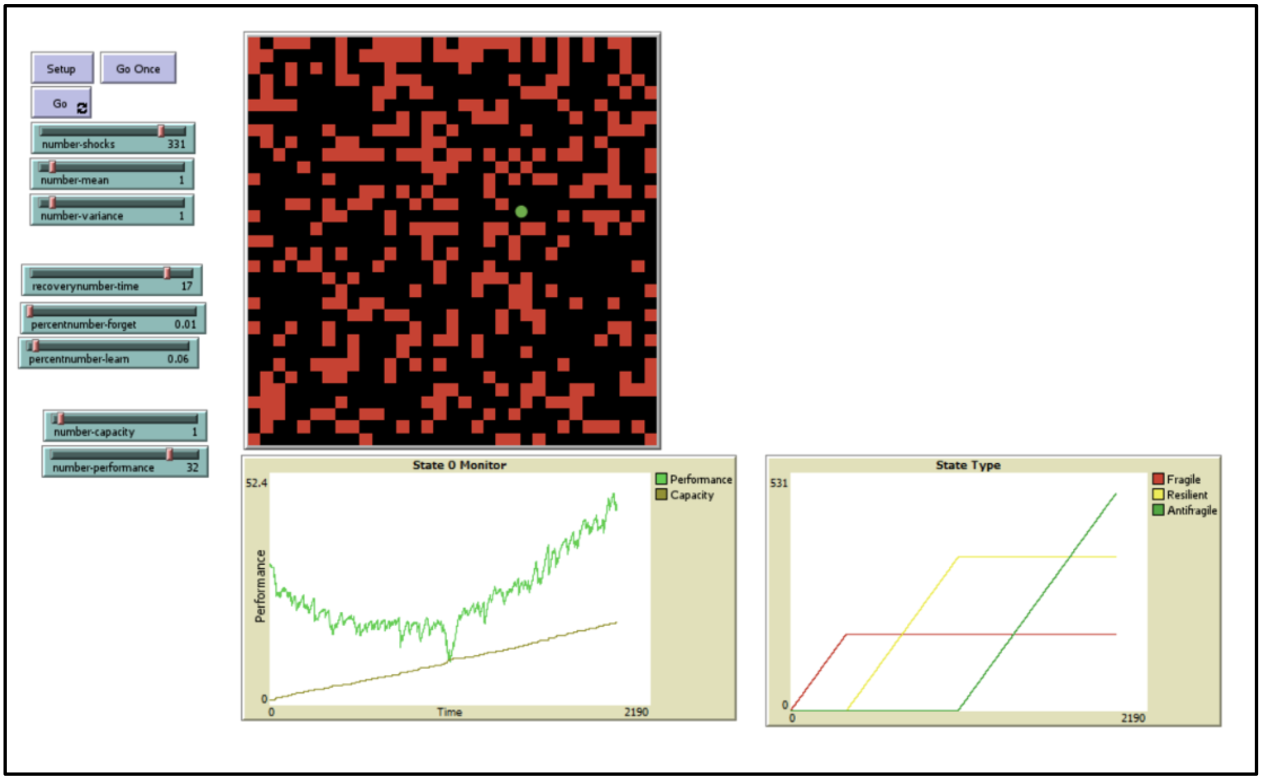
To translate the historical narrative to that of the model, the United States (the agent) was defined as having a lot of power. During this time, the United States was considered the preeminent power in the world relative to other states; however, visa-vis Al Qaeda, the United States was considered fragile. The initial *performance* of the agent was set up given a value of 32, very high.

During this same time, recall from previously in the chapter that Al Qaeda was flooding the environment with small scale shocks in order to learn from these experiences. To model this, the *number of shocks* was set to 350, and as a result are very dense. Furthermore, since the shocks are considered smaller scale (relative to that of a September 11, 2001, type attack), the *gamma mean* and *gamma variance* variables were set to a value of 1. The terminating condition for the simulation is when the simulation gets to 1000 tics.

Figure 34 provides a graphic of the output from the simulated run. Tracing the State 0 Monitor graph, one can see how the density of shocks leads to a trajectory of decreasing power for the United States over some period of time as they take a lot of hits from Al Qaeda and other Iraqi insurgent elements and suffer losses. However, at the same time, the propensity score(s) level of antifragility begins to rise as the United States begins to develop the capacity to learn from those shocks, thus demonstrating an emerging process for the United States as it is better able to learn, respond with agility and effectively convert power by the time of the Iraq surge in 2007.

Additionally, the State Type graph demonstrates the evolution of the United States from a fragile state to a resilient state, and a resilient state to an antifragile one.

Figure 34: Behavior of the United States during the Iraq War (2003-2010)



MODEL VALIDATION: AL QAEDA IN IRAQ

Examining the case study of the Iraq War from 2003-2010 but now from the vantage point of Al Qaeda, parameters from the case study were translated into the model to represent the internal conditions for Al Qaeda in Iraq during this time (Table 32). Additionally, environmental conditions in which Al Qaeda operated in was model (Table 33).

Table 32: Agent Initialization Conditions (Al Qaeda in Iraq)

Variable	**Parameter Value(s)**
Performance	5
Capacity	100
Agent Type	Antifragile
Percent-Learn	0.01
Percent-Forget	0.10
Recovery Time	5

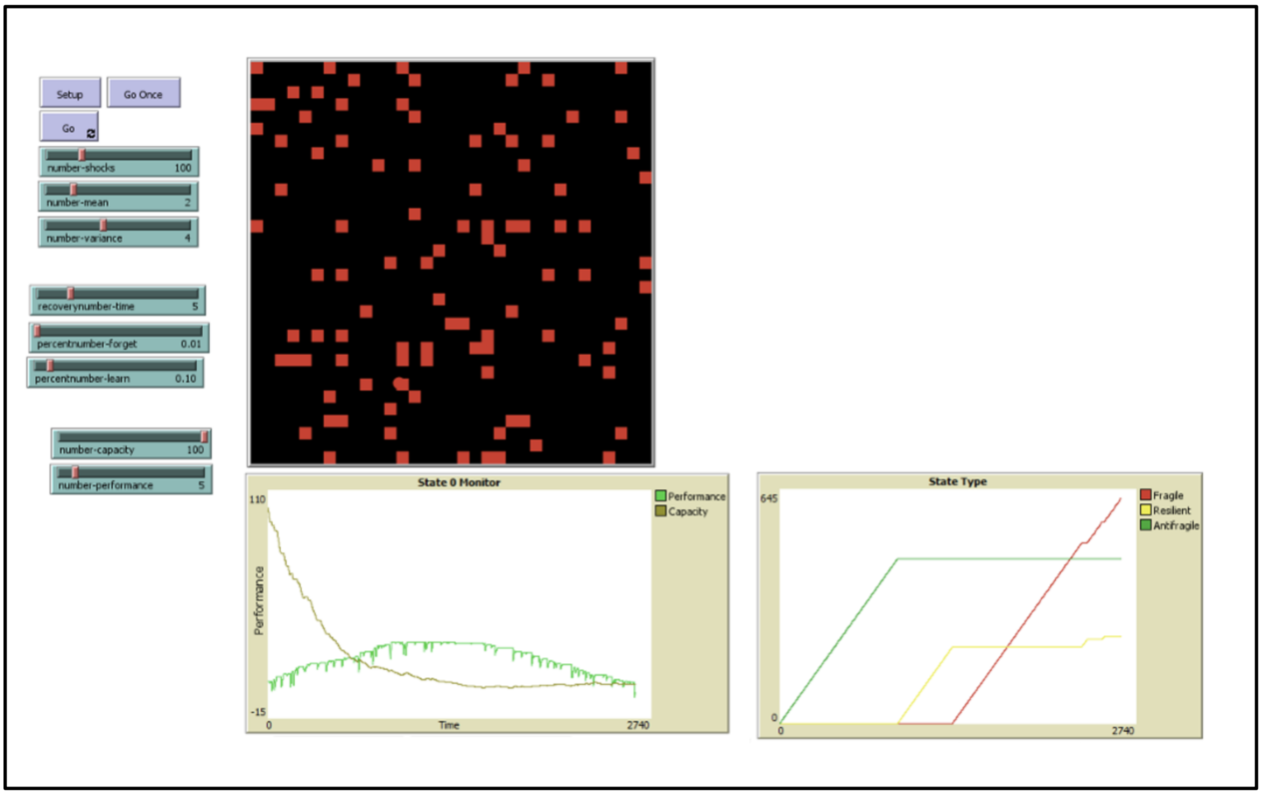
Table 33: Environment Initialization Conditions

Variable	**Parameter Value(s)**
Gamma Mean	2
Gamma Variance	4
Number of Shocks	100

This point in time simulates the time after the September 11, 2001, attacks and the 2003 Iraq invasion by the United States. Bin Laden's Al Qaeda had reached the highwater mark of its power by executing the largest scale, successful attack on the United States since the Pearl Harbor attack by Japan on December 7, 1941. With Sadaam Hussein deposed from power, the disenfranchisement of the Sunni minority began to coalesce around the ideologies of Bin Laden's Al Qaeda, seeking revenge against the United States for leaving them again without power in Iraq. Thus, Al Qaeda in Iraq emerged.

To translate the historical narrative to that of the model, the Al Qaeda in Iraq (the agent) considered relatively weak as it was just emerging in Iraq. The initial *performance* of the agent was set up given a value of 5. The War on Terror was in full effect during this time, and to model this, the *number of shocks* was set to 100. Similar to the conditions the United States was experiencing in the previous simulation run, they are very dense. Furthermore, since the shocks are considered small scale, so the *gamma mean* and *gamma variance* variables were set to values of 2 and 4, respectively. Finally, the terminating condition for the simulation is when the simulation gets to 1000 tics.

Figure 35: Evolutionary Behavior of Al Qaeda in Iraq during the Iraq War (2003-2010)



In Figure 35, Al Qaeda in Iraq begins with a large capacity; however, that capacity degrades over time. As the State 0 Monitor demonstrated, Al Qaeda in Iraq is antifragile at its origins, and keeps getting stronger as it hits shocks. However, by 2007 the United States is learning how to fight counterinsurgency (via the Surge), so it is no longer doing the sorts of shocks that the insurgency is antifragile with respect to (at least not so much). The tide turns for Al Qaeda in Iraq, and they become fragile, deteriorating and weakening over a period of time.

Figure 35 provides a graphic of the output from the simulated run. Tracing the State 0 Monitor graph, one can see how the density of shocks leads to a trajectory of increasing performance for the newly formed Al Qaeda in Iraq over some period of time, indicating a high level of learning. Similarly, the antifragile capacity of Al Qaeda in Iraq increases as they hit shocks frequently. As the State Type graph reveals, the initial high level of resiliency possessed by Al Qaeda in Iraq rapidly transitions into antifragility. Overall, Al Qaeda in Iraq began as weak but became a formidable adversary because of the degree to which they exhibited antifragility.

THE LEGACY: ISLAMIC STATE OF IRAQ AND THE LEVANT

Ongoing political failures by Iraqi leadership, coupled with a complex international environment, provided new opportunities for militants as the U.S. withdrawal from Iraq in 2012 helped create a power vacuum. By the year 2017, this matured insurgency has evolved and factionalized into many global extremist groups including Boko Haram and its affiliates in the Maghreb, Somalia, Syria, and Yemen. The most concerning, however, is that of the Islamic State of Iraq and Syria (ISIS) that has evolved into a global, state-like organization that at one time possessed more than 34,000 square miles of territory in Syria and included more than 150 miles of Mediterranean coastline.[177] As Simon Cottee writes in the Atlantic,

> Back in 2014, God was on the side of ISIS-or so it appeared, and so ISIS claimed, with some plausibility. The speed and scope of its ascent was extraordinary. In mid-June it seized Mosul, Iraq's second-largest city, and in the following months it annexed a Britain-sized swath of territory crossing Syria and Iraq. In his historic June 29 statement, in which he declared the restoration of the caliphate and announced Abu Bakr al-Baghdadi as its leader or caliph. (Cotee, 2017)[178]

The Islamic State of Iraq and Syria (ISIS) has demonstrated that their ideology and membership transcends borders. Although the United States and its coalition partners targeted ISIS with many air strikes, for a time ISIS seemed to emerge stronger and more determined to fulfill its prophecy. With ISIS permeating nations across the world, the United States, the world's guarantor of peace, faced a grim choice- put United States boots on the ground or remain steadfast with air strikes alone. Ultimately, the U.S. intervened militarily again, cooperating with various local organizations and rival factions within the Syrian civil war to attack ISIS and reduce its influence. What is most striking, however, are the differences between AQI and the ISIS.

ISIS employed a differing strategy and set of objectives from that of AQI. First, ISIS seeks to control territory. They have successfully demonstrated that they can do achieve this objective. From here, ISIS is then able to further advance its army to obtain more territory. Second, their tactics are different from that of AQI. Their brutal tactics include mass executions,

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[177] "ISIS Fast Facts." CNN, September 6, 2020. https://www.cnn.com/2014/08/08/world/isis-fast-facts/.
[178] Cottee, Simon. "ISIS Will Fail, but What About the Idea of ISIS?" The Atlantic, March 23, 2017. https://www.theatlantic.com/international/archive/2017/03/idea-of-isis-will-outlive-caliphate/520224/.

public beheadings, and rape to forcefully control people to join ISIS rather than through means of convincing people to join their cause through propaganda like Al Qaeda. Finally, ISIS has taken full advantage of another resource, social media. ISIS is far more prolific in the use of social media to enable the mobilization of lone wolves to attack the west. In fact, in a Congressional testimony from Daniel Byman when comparing Al Qaeda in Iraq to ISIS, "the bad news is that the Islamic State is far more successful in achieving its goals than Al Qaeda has been: like it or not, the Islamic State really is a "state" and that it controls territory and governs it. Its military presence is roiling Iraq and Syrian and the threat it poses extends to Jordan, Saudi Arabia, Egypt, Libya, Yemen and especially Lebanon."[179]

Today, the war with the Islamic State has turned the corner and moves into a new phase whereby the last of the Islamic State terrorists in Syria fell to Kurdish-backed forces in March 2019.[180] Without its leader, Abu Bakr al-Baghdadi, ISIS has remained surprisingly resilient, similar to that of Al Qaeda after the death of Osama bin Laden. Kathy Gilsinan reminds us how these Islamic violent extremist organizations proved to be more complicated than other violent extremist groups when she wrote in the Atlantic,

> So resilient, in fact, that its leadership in Iraq-which had declared allegiance to bin Laden in 2004 but always charted somewhat of an independent path-laid the foundation for what would become ISIS. Al-Qaeda in Iraq survived the death of its own leader, Abu Musab al-Zarqawi, in 2006, ultimately morphing and reconstituting itself years later as the Islamic State of Iraq and Syria, under Baghdadi's leadership. (Gilsinan, 2019)[181]

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[179] Byman, Daniel L. "Comparing Al Qaeda and ISIS: Different Goals, Different Targets." Brookings, April 29, 2015. https://www.brookings.edu/testimonies/comparing-al-qaeda-and-isis-different-goals-different-targets/.

[180] Gilsinan, Kathy. "The 'Caliphate' Is Gone. Where's the 'Caliph'?" The Atlantic, March 29, 2019. https://www.theatlantic.com/politics/archive/2019/03/where-isis-leader-baghdadi/586156/.

[181] Gilsinan, Kathy. "The 'Caliphate' Is Gone. Where's the 'Caliph'?"

Gilsinan continues by reminding us that while ISIS never achieved anything even close to the scale of 9/11 attacks, on U.S. soil, the trauma has completely reshaped how America behaves in the world, and ISIS will continue to morph with its change in environment. James, Rawlinson, a coalition spokesman, wrote in an email that ISIS is “actively transitioning to a [resurgent] network of sleeper cells in order to continue to aspire to a caliphate and threaten civilians throughout the region and around the world.”[182] So what of the current state of ISIS?

With the collapse of the Caliphate and being pushed out of Mosul and Raqqa, ISIS is far from defeated. ISIS still controls pockets of territory in Syria and in the Middle Euphrates River Valley along the Iraqi border and also lives on as a global brand, with terrorist affiliates in areas like Libya, Egypt, Yemen, Nigeria, Afghanistan, and Russia. Some say though the physical territory is lost, their adaptation to creating a “virtual caliphate” is very much alive: an ever-present threat to security and stability around the globe.[183] Defeating ISIS will not occur on the battlefield. Instead, it will involve addressing long term tasks of stabilization, reconstruction and development, the very same tasks omitted from the United States’ strategy in Iraq during the first Gulf War.

Even after America spent billions of dollars during two presidencies to defeat ISIS, deployed troops across Iraq and Syria, and dropped thousands of bombs, ISIS persists.[184] “Yes, they have lost much of their leadership. They have lost many of their capable men. But they’ve also managed to gain more experience and to recruit more people around them.”[185] That is, ISIS, though on the surface seems to be defeated, has taken their experience to learn. Masrour Barzani, the prime minister of Iraqi Kurdistan, states that in fact ISIS is not just surviving but

[182] Gilsinan, Kathy The ‘Caliphate’ Is Gone Where’s the ‘Caliph’?,
[183] *Where Is ISIS Today? Middle East Institute*, 2019. https://www.mei.edu/multimedia/video/where-isis-today.
[184] Giglio, Mike, and Kathy Gilsinan. “The Inconvenient Truth About ISIS.” The Atlantic, February 14, 2020. https://www.theatlantic.com/politics/archive/2020/02/kurdish-leader-isis-conflict-iraq-iran/606502/.
[185] Giglio, Mike, and Kathy Gilsinan. “The Inconvenient Truth About ISIS.”

rather thriving. How is this possible? The main reason for the ISIS resurgence is the persistence of the same conditions that allowed it to rise up in the first place. As Mike Giglio and Kathy Gilsinan write in their piece, *The Inconvenient Truth About ISIS* in the Atlantic,

Syria remains in chaos. U.S and Iraqi leaders have failed to solve problems such as corruption, poor governance, sectarianism, and economic malaise. Much of the Sunni-majority areas that were ISIS strongholds still like in destruction, largely from U.S. airstrikes, and some are not under control of the Iran-backed Shiite militias, which have antagonized much of the population with their sectarian tactics. (Gilsinan, 2020)[186]

From a loose group of tribal insurgents to a formalized state-like organization, there can be no question that the rapid evolution and rise of Al Qaeda and ISIS has only strengthened with each new challenge it faces. Despite what the assumptions of realism tell us, these non-state actors have amassed sufficient power to influence and cause considerable change within the international system that has as a result drawn the United States and her allies into a prolonged, bloody, and costly war.[187] Furthermore, Al Qaeda's dominance over the United States military is an odd curiosity in this tale. With increased stress and chaos and the ability to improvise quickly with minimal resources, Al Qaeda was able to grow and prosper into a formidable opponent that has drawn the world's greatest superpower into the longest, costliest war in history.

CONCLUSION

When overlaying the results of the simulation model experiments with the historical events of the first and second Iraq Wars, it can be discerned that the unintended consequences of the original Iraq War (1990-1991) impacted the latter Iraq War (2003-2011) and emerged primarily as a result of a lack of learning on behalf of the United States. Though militarily the

[186] Giglio, Mike, and Kathy Gilsinan. "The Inconvenient Truth About ISIS."
[187] Realism argues that interactions between states are the main relationships of interest.

first Iraq War was a decisive victory for the United States and demonstrated many of Sterling's design principles of antifragility such as redundancy, layered systems, and ensuring everyone has skin the game, antifragility is a long-term game. That having a history of surviving past shocks became important later on for the United States during the second Iraq War when the conventional military on military warfare morphed into something more reminiscent of the conflict in Vietnam. The United States' previous lack of exposure to successful nation building, conflicts with insurgencies all culminated into its forgetfulness of the lessons of Vietnam. This not only caught the United States flatfooted in 2003 after Saddam Hussein was deposed but made it hard for the US to pivot from their previous mental models of winning by conventual warfare (strategy) to filling a power vacuum with a functioning, pro-western government and preventing the fulling of that vacuum.

Additionally, the United States saw a long recovery period between the Vietnam War and the second Iraq War; thus, its ability to absorb new shocks without dying (performance) was degraded. As such, this has resulted in the longest armed conflict the United States has ever been involved in. With the conflicts in Iraq and Afghanistan, the United States had a rare and historical opportunity to learn from its previous experiences and change course to ensure the same mistakes were not experienced. However, the rise of nonstate, transnational terrorist organizations such as Al Qaeda, Al Qaeda in Iraq, and ISIS that were able to outmaneuver the United States at various periods of time prove that learning was not a forte of the United States. From advanced, high technology equipment to learning about tribal networks and concepts of honor, the post-industrial, modern advanced United States military had a steep learning curve it seems it still has yet to fully overcome. Overall, "the expansion of violent extremist movements such as Al Qaeda in Iraq are more a product of instability than their primary driver. That is, their expansion is due more to radicalization during a crisis beforehand and owes more to fighting between their enemies than their strengths."[188] Simply put, violent extremist movements gain from disorder and volatility and as a result are antifragile.

As the lessons of entanglements in the Middle East remain to be learned and the consequences of those engagements resurrect themselves from the rubble, the United States turns its eye to a new enemy, one that has been amassing resources to execute its grand strategy as a means to convert power on an unrivaled scale. This inability to convert power would have haunting consequences for the United States military in Iraq and the United States in the international system and impact its overall levels of fragility later as they would have to pivot their focus and attention from the Middle East to that of the Indo-Pacific.

[188] Atwood, Richard, Comfort Ero, and Dino Mahtani. "Exploiting Disorder: Al-Qaeda and the Islamic State." International Crisis Group, March 14, 2016. https://www.crisisgroup.org/global/exploiting-disorder-al-qaeda-and-islamic-state.

CHINA, THE UNITED STATES, AND THE INDO-PACIFIC

The case study on the current great power competition between the United States and China in the Indo-Pacific possesses many parallels to that of the Iraq War case study. Caught up in lingering entanglements in the Middle East, the United States has only recently turned its attention to the Indo-Pacific region and China's activities to erode American values and alter the current international rules-based order. The fundamental difference, however, in this scenario is that we are examining two states engaged in a great power competition. China has rapidly ascended to the top of the political, international order through its economic transformation, rapid military modernization, and Belt and Road Initiative. Both the economic reforms combined with their military modernization efforts over the past twenty-five years have well positioned China to execute their Belt and Road strategy bidirectionally into Africa and the Indo-Pacific. Similar to the pre-September 11, 2001, attacks by Al Qaeda, China is actively probing the international system through their acquisition of land and resources in the South China Sea (SCS) to understand and learn from the types of responses they evoke. These probes can be viewed as localized shocks such that China can learn at a local level what it can "get away with" without greater systemic consequence or failure. That is, China is testing how much the international community will tolerate just shy of evoking a war, a war which China is actively preparing for.

As Tanguy Stuye de Sweiland writes in, *The Indo-Pacific: The New Great Game* between China and the United States,

> The Asia-Pacific region currently constitutes the epicenter of world affairs and brings together the majority of great powers (emerging and confirmed), most nuclear powers and more than one-third of the world population. Although the

> regional has emerged as the new major economic driving force globally, it remains subject to numerous security challenges (including piracy, terrorism, proliferation, natural resources, and border issues.) Economic interdependence has not removed the risk of war, especially in the Korean Peninsula, over the Taiwan issue, and over maritime border disputes in the South China Sea. As general M. Dempsey summed it up, 'All of the trends, demographic trends, geopolitical trends, economic trends and military trends are shifting toward the Pacific. So, our strategic challenges in the future will largely emanate out of the Pacific region, but also the littorals of the Indian Ocean.' In the current context of the transition of the balance of power towards Asia, the zone extending from the Gulf of Bengal to the Sea of Japan is of even more vital interest to Washington. And although the United States is still dominant in the Pacific, it is less so than in the past as Asia undergoes profound changes. (Swielande, 2020) [189]

As the United States and other nations in the Indo-Pacific region converge on China as the next great threat, understanding how China rose to become the regional power it is today is important. Furthermore, this chapter focuses on understanding how China is systemically seeking to dominate the Indo-Pacific region and become more antifragile than that of the United States.

THE INTERNATIONAL INTEGRATION OF CHINA

Prior to the establishment of the Republic of China in 1912, China possessed a long history of dynasty rule whose legacy rippled throughout the globe and still impacts the modern

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[189] de Sweilande, T.anguy Struye. "The Indo-Pacific: The New Great Game between China and the United States." *Dessein B. (eds) Interpreting China as a Regional and Global Power. Politics and Development in Contemporary China Series*, 2014, 169–90. https://doi.org/10.1057/9781137450302_10.

world as we know it today. Dynasties by their very nature are not varied diversified governance structures; rather, they are centralized structures that perpetuate rule of a nation from within the same family. Though this type of governance structure is not commensurate with antifragile system design principles, it was capable of producing benefits for both China and the global community such as the Silk Road, the largest trade network the world had ever seen. [190] The establishment of this trade thoroughfare helped to enhance the Chinese economy by allowing traders to travel as far away as Europe and the Horn of Africa to conduct their affairs in places previously inaccessible.[191] In addition to the creation of this ancient network of trade routes, the Chinese dynasties of this time perpetuated the development of papermaking, gunpowder, and early ripening rice as an agricultural achievement. Despite these achievements occurring centuries ago, the consistent thread that runs through both ancient and modern-day China is their global view and reach, as discussed later in this chapter. Modern day China saw its last imperial dynasty end in 1912.

When major combat in the Chinese Civil War ended in 1949, the Chinese Communist Party gained control of most of mainland China, and Communist Party Chairman Mao Zedong proclaimed the establishment of the People's Republic of China on September 21, 1949.[192] Changes such as the one from imperial dynasty to a communist-ruled authoritarian regime occurred over the coming decades.

Throughout the 1950s, China underwent the Great Leap Forward, an economic and social campaign with the aim of transforming the primarily agrarian economy into a communist society. With farming now collectivized and labor-intensive industry introduced, the results were

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[190] "Timeline of Chinese History and Dynasties." Asia for Educators. Columbia University, 2020. http://afe.easia.columbia.edu/timelines/china_timeline.htm.
[191] Timeline of Chinese History and Dynasties." Asia for Educators.
[192] Timeline of Chinese History and Dynasties." Asia for Educators.

an economic breakdown and the abandonment of the Great Leap Forward just after two years. The 1960s saw the launch of Mao's Cultural Revolution, a sociopolitical movement that sought to preserve Chinese Communism by purging remnants of capitalist and traditionalist elements from Chinese society, again with the result producing massive social, economic, and political upheaval in China. During this time, United States President Richard Nixon made a historic trip to China in 1972 with the hope of gaining more leverage over the then Soviet Union by appealing to China. Nixon's meeting with Mao Zedong results in the signing of the Shanghai Communiqué with Premier Zhous Enlai, which set the stage for improved U.S-Sino relations by allowing the United States and China to discuss contentious issues such as Taiwan. The normalization of relations between the United States and China culminated in 1979, when the United States President Jimmy Carter established full diplomatic relations with the People's Republic of China. By 1984, the United States become China's third-largest trading partner. From the mid 1980s to the early 1990s, China established an "open-door policy" with regard to foreign investment, encouraging development of a market economy and private sector. It was in 2000 that United States President Bill Clinton signed the U.S.-China Relations Act of 2000, granting Beijing permanent normal trade relations with the United States and paving the way for China to join the World Trade Organization in 2001.

In a relatively short period of time, both China's governance structure and economy saw periods of explosive growth. The economy in particular underwent a transformation from a communist, command economy to one much more decentralized and diversified, with its reach spanning the globe. According to a report issued by the Congressional Research Service,

> Prior to the initiation of economic reforms and trade liberalization nearly 40 years ago, China maintained politics that kept the economy very poor, stagnant,

> centrally controlled, vastly inefficient, and relatively isolated from the global economy. Since opening up to foreign trade and investment and implementation free-market reforms in 1979, China has been among the world's fastest-growing economies, with real annual gross domestic product (GDP) growth averaging 9.5% through 2018, a pace described by the World Bank as "the fastest sustained expansion by a major economy in history." (Congressional Research Service, 2019)[193]

Although China bears little resemblance to the communist command economy of its past, China's regulatory developments within their economy put into question whether China's leaders ever really sought to comply with their World Trade Organization commitments. Philip Leavy wrote, "today, many United States Trade Representatives have expressed doubts and outrage that the west should have ever admitted China into the World Trade Organization, whose rules-based system seemingly enabled Beijing to prosper even as it enraged in questionable behavior."[194] In other words, despite joining an international organization whereby nations are expected to acquiesce to a rules-based order and conform to liberal and economic norms, China has remained obstinately defiant as it receives protectionism despite its negative impact on developed nations. Roselyn Hsueh underscores this point in her piece, *How China Outsmarted the WTO*,

> Throughout the 1990s many of the world's telecommunications equipment makers and global service providers operated in China and enjoyed significant market share. But this embrace of market competition abruptly halted in 1998. After foreign technology and knowledge transfers helped to modernize

[193] U.S. Library of Congress. Congressional Research Service. *China's Economic Rise: History, Trends, Challenges, and Implications for the United States* RL33534

[194] Levy, Philip. "Was Letting China Into the WTO a Mistake?: Why There Were No Better Alternatives." Foreign Affairs, April 2, 2018. https://www.foreignaffairs.com/articles/china/2018-04-02/was-letting-china-wto-mistake.

> telecommunications networks, central leaders forced the divestment of FDI in basic telecommunications services in order to retain ownership and management in state's hands…As economies around the world assess the effects of neoliberalism-synonymous to deregulated markets and privatization-China has embraced a mixed economy unlike no other we have seen before. Instead of turning China into a liberal market economy, with all its attendant problems, WTO membership has allowed China to achieve steady economic grown in the shadow of the global debt and financial crises of the 2000s. The Chinese leadership has pursued state priorities, including the modernization and management of information infrastructure, hailing free trade yet not complying with its WTO commitments. What the Chinese experience has made clear is that in the age of globalization, it is very possible to have freer markets and more authoritarian rule. (Hsueh, 2011) [195]

There is little doubt that the modern-day Chinese economy was born, in part, out of the United States' strong desire and urge to participate in a global, free-market economy, believing this would help promote free trade by China who would now be required as members of the World Trade Organization to adhere to the institution's principles that emphasize low and predictable trade barriers. Xiaodong Zhu stresses this dynamic growth by China in *Understanding China's Growth: Past, Present, and Future* when he writes,

> The pace and scale of China's economic transformation have no historical precedent. In 1978, China was one of the poorest countries in the world…Since then, China's real per capita GDP has grown at an average rate exceeding 8

[195] Hsueh, Roselyn. "How China Outsmarted the WTO." The Regulatory Review, December 26, 2011. https://www.theregreview.org/2011/12/26/how-china-outsmarted-the-wto/.

> percent per year. This rapid and sustained improvement in average living standard has occurred in a country with more than 20 percent of the world's population so that China is now the second-largest economy in the world. (Zhu, 2012)[196]

However, it is not just the rapid economic ascendance of China on the international stage that is remarkable and unprecedented. Their military modernization efforts have transformed the People's Liberation Army into a technologically advanced, top-tier, global force.

Now considered a leader in areas including artificial intelligence and anti-ship ballistic missiles, China's military turning point came about in the 1990s when the Chinese Communist Party bore witness to the United States flexing its own military might in their hemisphere during the Gulf War. With this example of modern military warfare in Iraq broadcast on television cables all over the world, Chinese leaders acknowledged that they lacked the technology to wage a modern war and prevent foreign powers from intervening in the region. As a result, defense spending was immediately increased, and investments made in new weapons to enhance anti-access area denial (A2/AD). It would seem that the Gulf War would produce yet another unintended consequence for the United States what would come back to haunt them in the future. Arguably this reflects one of the key consequences of thinking about the world in terms of antifragility. Even successes can sow the seeds for subsequent failures by helping potential adversaries learn and thereby grow stronger.

According to Lindsay Maizland of the Council on Foreign Relations, "another shift began in 2012, when President Xi Jinping came to power. Championing what he calls the Chinese Dream, a vision to restore China's great-power status, Xi has gone further to push military

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[196] Zhu, Xiaodong. "Understanding China's Growth: Past, Present, and Future." *Journal of Economic Perspectives* 26, no. 4 (2012): 103–24. https://doi.org/10.1257/jep.26.4.103

reform than his predecessors."[197] The importance of defense spending for Xi's 'Chinese Dream' is underscored by the almost doubling of China's official defense spending from $97.2 billion U.S. dollars in 2012 to $170.4 billion U.S. dollars in 2018.[198] Furthermore, the United States' Defense Intelligence Agency (DIA) projects expected advance in areas such as nuclear deterrence, power projection, cyberspace, space and electromagnetic spectrum operations will continue to be critical components of the People's Liberation Army's developing capabilities.[199] What, then, is the intention of China's military modernization efforts? As China's Military Strategy states,

> China's destiny is vitally interrelated with that of the world as whole. A prosperous and stable world would provide China with opportunities, which China's peaceful development also offers an opportunity for the whole world. China will unswervingly follow the path of peaceful development, pursue an independent foreign policy of peace and a national defense policy that is defensive in nature, oppose hegemonism and power politics in all forms, and will never seek hegemony or expansion. China's armed forces will remain a staunch force in maintaining world peace. (Defense Intelligence Agency, 2019) [200]

China's preferred theater of which it seeks to maintain world peace through its rapid economic ascent and modernization of its military is in the Indo-Pacific.

SETTING THE STAGE: FROM ASIA-PACIFIC TO INDO-PACIFIC

For thirty years (1980-2010), 'Asia-Pacific' was the nomenclature used in the of United States defense strategy doctrine; however, recently, the Indo-Pacific has become the replacement

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[197] Maizland, Lindsay. "China's Modernizing Military." Council on Foreign Affairs, February 5, 2020. https://www.cfr.org/backgrounder/chinas-modernizing-military.

[198] China Military Power: Modernizing a Force to Fight and Win § (2018).

[199] China Military Power: Modernizing a Force to Fight and Win § (2018).

[200] China Military Power: Modernizing a Force to Fight and Win § (2018).

vision for the United States, Japan, Australia, the ten Association of Southeast Asian Nations (ASEAN) states and major European powers. "The 'Indo-Pacific' or 'Indo-Pacific region' has enjoyed growing popularity over ten years as a geographical and strategic construct in the foreign and security policy discourse in Japan, the United States, Australia, India, France and some Southeast Asian states."[201] According to Rory Medcalf of the Australian National University, in the decade of its arrival and ascendancy, the idea of the Indo-Pacific rather than Asia-Pacific heralded a new era of power rivalry, a world away from the optimism of globalization. As Graeme Dobell writes,

> The Indo-Pacific had become the global centre of gravity, in wealth and population, but also the heartland of military might and latent conflict. Confrontation was trumping cooperation. From the Gulf of Aden to Papua New Guinea, the board was uncomfortably set for a great game with many layers and many players. (Dobell, 2020) [202]

In his latest book, *Contest for the Indo-Pacific: Why China Won't Map the Future*, Rory Medcalf writes, "the Indo-Pacific has become the vast ground zero for nuclear deterrence and risk: it is the epicentre of a 'second nuclear age.'"[203] Overall, the Indo-Pacific region gained more importance geopolitically and geo-economically over the last two decades than any other region, beginning with United States President Barack Obama's East Asia Strategy, which represented a significant shift in the foreign policy of the United states by taking the nation's focus from the Middle East to East Asian countries. President Obama's 2012 "Pivot to East

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[201] Heiduk, Felix, and Gundrun Wacker. "From Asia-Pacific to Indo-Pacific" Significance, Implementation and Challenges, January 7, 2020. https://doi.org/10.18449/2020RP09
[202] Dobell, Graeme. "Making the Indo-Pacific." The Strategish. Australian Strategic Policy Institute, March 2, 2020. https://www.aspistrategist.org.au/making-the-indo-pacific/.
[203] Dobell, Graeme. "Coexistence or War in the Indo-Pacific." The Strategist. Australian Strategic Policy Institute, March 9, 2020. https://www.aspistrategist.org.au/coexistence-or-war-in-the-indo-pacific/.

Asia" codified this regional strategy by emphasizing key areas pertaining to strengthening bilateral security alliances, enhancing regional multilateral institutions, expanding trade and investment, advancing democracy and human rights, and a broad-based military presence.[204] Though there was much in the way of commentary since President Obama's announcement in 2011, some contend that the dramatic shift in United States foreign policy was not such a dramatic shift after all. According to David Shambaugh, Professor of Political Science and International Affairs at George Washington University,

> The pivot-or rebalancing-is not a new policy; it is a deepening and broadening of previous commitments. Part of this broadening includes a geographic expansion of sorts-by including India and the Indian Ocean in the broader Asia initiative. Thus, it is not just an East Asian initiative: US-India relations are growing very robustly and positively even though the five bilateral alliances remain the bedrock of US relations in the region. Engagement of China also continues as a central element in US strategy and diplomacy. …The resources devoted to the Asia-Pacific are being increased-both absolutely and relatively vis-à-vis other regions of the world, with Southeast Asia and the South Pacific receiving new attention. It is also very important to recognize that the new pivot policy is not being unilaterally thrust upon Asian nations by the United States-quite the contrary. Although the Obama administration began planning the reorientation as soon as it entered office in 2009, with an eye toward winding down the wars in Iraq and Afghanistan, it was the 2009-10 'year of assertiveness' by China that triggered

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[204] U.S. Library of Congress. Congressional Research Service. *Pivot to the Pacific? The Obama Administration's "Rebalancing" Toward Asia* by Mark E. Manyin, Stephen Daggett, Ben Dolven, Susan V. Lawrence, Michael F. Martin, Ronald O'Rourke, and Bruce Vaughn. R2448

> many Asian states to grow sharply concerned about Beijing and therefore ask Washington to increase its presence and attention to the region Thus, to the extent China is an element of focus in the pivot strategy (and it is), Beijing's own assertive behavior is the cause. (Shambaugh, 2013)[205]

With the 2016 United States Presidential election, President Donald Trump remained resolute on seeing through the pivot to Asia. According to United States Secretary of State, Mike Pompeo, President Donald Trump has made U.S. engagement in the Indo-Pacific region a top priority of his Administration. With over $1.9 trillion U.S. dollars in two-way trade, the economic importance of the Indo-Pacific cannot be understated.[206] Additionally, the $4.5 billion U.S. dollars in foreign assistance from the U.S. Agency for International Development (USAID) only further demonstrates the investment the United States is willing to make to launch new resources and build partnerships in the region.[207] The new Biden administration has continued to focus its attention on the Indo-Pacific region, although it has slightly diverted from the Trump administration's policies as later discussed in the chapter.

SETTING THE STAGE: THE NEW SILK ROAD

China, too, has taken interest in the Indo-Pacific region. Presently, China is flexing its economic strength throughout the Indo-Pacific to grasp influence throughout the region via its Belt and Road Initiative (BRI). On the surface, China's 2013 the Belt and Road Initiative is a global infrastructure development strategy used to invest in over 70 nations, an international organization stretching from East Asia to Europe. As the cornerstone of President Xi Jinping's foreign policy, the Belt and Road Initiative uses a two-pronged approach. First, the Silk Road

[205] Shambaugh, David. "Assessing the US 'Pivot' to Asia." *Strategic Studies Quarterly* 7, no. 2 (2013): 10–19. https://www.jstor.org/stable/pdf/26270763.pdf.
[206] Pompeo, Michael, A Free and Open Indo-Pacific: Advancing A Shared Narrative § (2019).
[207] Pompeo, Michael, A Free and Open Indo-Pacific: Advancing A Shared Narrative § (2019).

Economic Belt addresses President Xi's vision for "creating a network of railways, energy pipelines, highways and streamlined border crossings." [208] Second, the Maritime Silk Road focuses its resources on expanding maritime trade traffic, port development investments from the Indian Ocean to East Africa and parts of Europe.[209] What is most astounding about President Xi's initiative, however, is the overwhelming number of nations that have signed on to projects or indicated interest. According to Andrew Chatzky and James McBride,

> To date, more than sixty countries-accounting for two-thirds of the world's population-have signed on to projects or indicated interest in doing so. Analysts estimate the largest so far to be the estimated $60 billion China-Pakistan Economic Corridor, a collection of projects connecting China to Pakistan's Gwadar Port on the Arabian Sea. In total, China has already spent an estimated $200 billion on such efforts. Morgan Stanley has predicted China's overall expenses over the life of the BRI could reach $1.2-1.3 trillion by 2027, though estimates on total investments vary. (Chatzky and McBride, 2020) [210]

Given the overwhelmingly ambitious nature of Xi's initiative, what are the major takeaways from the Belt and Road Initiative? According to a study from the Mercator Institute for China Studies, "over the past year, three themes have emerged that provide the context for Xi's signature initiative: the BRI is a long-term project, it has a global scope, and it is not limited to economic goals, but also has a growing security component."[211] As the study reveals,

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[208] Chatzky, Andrew, and James McBride. "China's Massive Belt and Road Initiative." Council on Foreign Relations, January 28, 2020. https://www.cfr.org/backgrounder/chinas-massive-belt-and-road-initiative.
[209] Chatzky, Andrew, and James McBride. "China's Massive Belt and Road Initiative."
[210] Chatzky, Andrew, and James McBride. "China's Massive Belt and Road Initiative."
[211] "Mapping the Belt and Road Initiative: This Is Where We Stand." Mercator Institute for China Studies, June 7, 2018. https://merics.org/en/tracker/mapping-belt-and-road-initiative-where-we-stand.

The 'Vision for Maritime Cooperation' includes a sub-chapter devoted to security issues as one of Beijing's cooperation priorities. In view of China's ballooning investments and growing Chinese expat communities in risk-prone countries, Beijing has become convinced that is has to take security concerns along the BRI routes into its own hands. In 2015, China adopted an anti-terrorism law allowing for foreign missions of PLA units, and it opened its first overseas military base in Djibouti, a hub of the Maritime Silk Road. A new industry of Chinese private security companies is rapidly developing, providing protections to BRI projects. Beijing also touts its technological, law enforcement and military capabilities to countries covered by the BRI on security-related issues like satellite navigation, disaster management and combating crime.[212] Furthermore, the infrastructure projects are executed with Chinese labor and oftentimes fail to be delivered upon. Finally, the loans China gives to invest in many of these small, Pacific Island nations are considered to be unserviceable. The use of "debt-trap" diplomacy in the Indo-Pacific is being used to gain leverage over strategically vital assets like ports, airports, or electricity providers in nations like Papua New Guinea and Vanuatu. Between 2011 and 2018, China committed loans to the region worth US$6 billion-around 21 percent of regional Gross Domestic Product (GDP). (Metrics.org, 2018)[213]

One Belt, One Road is certainly not without its criticism. "Some analysts see the project as an unsettling extension of China's rising power, and as the costs of many of the projects have

[212] "Mapping the Belt and Road Initiative: This Is Where We Stand." Mercator Institute for China Studies
[213] "Mapping the Belt and Road Initiative: This Is Where We Stand." Mercator Institute for China Studies

skyrocketed, opposition has grown in some countries."[214] The United States views the project as a Trojan horse of sorts used to thinly veil China-led regional and military development in the Indo-Pacific. Mainly, many states are concerned because of possible Chinese influence that is inherent to this initiative along with the sundry of strings attached that more often than not leave the borrowing nation indebted to China and conceding sovereign land. In short, President's Xi's actions in initiating the Belt and Road initiative "serves as a pushback against the much-touted U.S. 'pivot to Asia,' as well as a way for China to develop investment opportunities, cultivate export markets, and boost Chinese incomes and domestic consumption."[215]

Realist perspectives, especially the concept of the security dilemma, are particularly prominent among scholars and analysts who seek to understand and explain the rise of China. For example, a security dilemma arises when a state's efforts to increase its security are interpreted by another state as a threat to its security, prompting the second state to upgrade its own defenses. What both sides view as reasonable defensive preparations, can spiral into dangerous (and expensive) tit-for-tat competition for military superiority. As Shelley Rigger writes in her piece, *Theory and Policy in Sino-U.S. Relations in the American Journal of Chinese Studies*,

> The security dilemma is a valuable concept for thinking about the rise of China. China's increasing wealth has provided resources for the PRC to invest in military modernization. Modernization does not, in itself, imply aggressive intent. Nonetheless, China's neighbors have reacted to its military modernization by adopting policies consistent with another Realist concept: balancing. They have

[214] Chatzky, Andrew, and James McBride. "China's Massive Belt and Road Initiative." Council on Foreign Relations, January 28, 2020. https://www.cfr.org/backgrounder/chinas-massive-belt-and-road-initiative.
[215] Chatzky, Andrew, and James McBride. "China's Massive Belt and Road Initiative."

> upgraded their own militaries (internal balancing) and strengthened their alliance relationships (external balancing.) The balancing behavior suggests these states feel threatened by China's rising military power. …Meanwhile on the other side of the coin, it's hard for China's strategists to see the neighbor's reactions as defensive because many of them believe the U.S. has the intention to abort China's rise. To them, the balancing behavior of the neighboring states looks like a tightening noose, with the U.S. holding the loose end of the rope. (Rigger, 2014)[216]

What does China's rise in the Indo-Pacific mean for the United States?

NOT IF, BUT WHEN: SHOWDOWN IN THE EAST OR WEST?

Equally important to the intent of China's expansionism, is the direction in which this will transpire has monumental political, economic, and military consequences. Go west, and China might be successful at economically de-coupling from the United States such that when conflict occurs, China is in a better position, economically, to confront the United States. Go east, and China strategically isolates the United States from her allies in the Indo-Pacific in the hopes of winning the ultimate prize, Taiwan.

With China's recent rise in visibility as Africa's main financier, African borrowers have built roads, installed electrical grids, and modernized their airports with Chinese finance. In a report by Deborah Brautigam, Yufan Huang, and Kevin Acker of the John's Hopkin's China Africa Research Initiative (CARI),

> According to the World Bank's International Debt Statistics, in 2017, official bilateral credits from China accounted for 62 percent of bilateral official credits,

[216] Rigger, Shelley. "Theory and Policy in Sino-U.S. Relations." *American Journal of Chinese Studies* 21 (June 2014): 143–50. https://www.jstor.org/stable/44289344.

> or about 23 percent of all public and publicly guaranteed debt in sub-Saharan Africa. In 2018, for the 40 low-income African countries, Chinese debt came to 50 percent of bilateral lending, and 17 percent of public and publicly guaranteed (PPG) debt in this subset of countries. (Brautigam, et. al.,2020) [217]

While this may seem positive for those African nations in need of a lender to improve infrastructure and invest in agriculture, the report finds that Chinese financiers are not transparent and do not provide data on the loans they offer to individual overseas borrowers. Furthermore,

> China's actions along the Belt and Road range from an expanding military agenda, psychological and political influence campaigns toting benefits of authoritarianism, and the use of telecommunications technology to surveil other governments. The opacity of Chinese infrastructure loans and investment is detrimental to U.S companies' ability to compete and increases states' vulnerability to debt leveraging. This risk is exacerbated by China's courtship of Africa political and military leaders through visits from top leadership. U.S. national security concerns are particularly potent, as the Chinese military base in Djibouti has become the epitomizing symbol of China's aggression along the Belt and Road. While these concerns are valid and broadly defined by U.S.-China policy experts, they overshadow the positive outcomes of the BRI and thwart any opportunity the United States may have to work along China to uplift African states. [218]

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[217] "Risky Business: New Data on Chinese Loans and Africa's Debt Problem." Risky Business: New Data on Chinese Loans and Africa's Debt Problem | Johns Hopkins SAIS, July 2, 2020. https://sais.jhu.edu/news-press/event-recap/risky-business-new-data-chinese-loans-and-africa%E2%80%99s-debt-problem.

[218] Risberg, Pearl. "The Give-and-Take of BRI in Africa." New Perspectives in Foreign Policy. Center for Strategic & International Studies, April 8, 2019. https://www.csis.org/give-and-take-bri-africa.

Of the thirty-nine African countries on the Belt and Road official website, China's government financing is the principal creditor to only three countries: Congo-Brazzaville, Djibouti, and Zambia, with the Chinese Communist Party expressing particular interest in a nation with less than one million people, Djibouti. [219] For example, the Ethiopian-Djiboutian electric railway that cost $4 billion dollars was completed in 2017. Additionally, the Export-Import Bank of China funded a $300 million-plus water pipeline system that will transport drinking water from Ethiopia to Djibouti. Why has China taken such an economic interest in the tiny Horn of Africa country?

Djibouti may seem insignificant on the surface; however, as Monica Wang writes in *China's Strategy in Djibouti: Mixing Commercial and Military Interests*, the nation has become "a testing ground for the mixing of China's commercial and military interests abroad."[220] Home to the only U.S. military base in Africa, Djbouti has now become an increasingly significant focal point in U.S.-China relations due to the construction of the Doraleh Multipurpose Port, constructed by Djibouti and its partner, the state-owned China Merchants Group (CMG). A few months later, China's first overseas military base was completed just a few minutes away from the commercial port at Doraleh. Built for the People's Liberation Army Navy, the military base now allows for the People's Liberation Army Navy to have oversight into one of the most important maritime chokepoints in the world, the Gulf of Aden.

The strategic importance of this area along with the construction of a Chinese military base is not coincidental. Djibouti's strategic location on the eastern edge of the African continent and the western shore of the Indian Ocean, allows for the Chinese Communist Party a

[219] Risberg, Pearl. "The Give-and-Take of BRI in Africa."
[220] "China's Strategy in Djibouti: Mixing Commercial and Military Interests." Council on Foreign Relations, April 13, 2018. https://www.cfr.org/blog/chinas-strategy-djibouti-mixing-commercial-and-military-interests.

front row seat to the Bab-el-Mandeb Strait through which an estimated 12.5-20 percent of global trade passes each year. It should be noted that Djibouti is also home to Camp Lemonier, where more than 4,000 American personnel are stationed for the Combined Joint Task Force-Horn of Africa.[221]

Wilson Vorndick summarizes the significant investment China has made in Africa when he writes,

> The amount of Chinese military and economic activity around these locations has been significant. Yun Sun from the Stimson Center points out that in a 10-year period, beginning in 2008 when China began anti-piracy operations in the Gulf of Aden, 'China has dispatched 30 naval-escort task forces to the region, at a state rate of three a year.' On the African continent, China has promised over $100 million in military aid to the African Union, a new pledge of over $60 billion in financial support, and registered an 8,000-strong peace keeping force with the United Nations.[222]

What then of the United States' strategy to counter Chinese aggression and malign influence in Africa in the "America first" age of President Donald Trump? On October 5, 2018, President Trump signed into law the Better Utilization of Investments Leading to Development (BUILD) act, a $60 billion-dollar investment structured under the United States International Development Finance Corporation (IDFC).[223] However, as Todd Moss, an analyst for the Center for Global Development concedes, "the Chinese model is bigger and quicker, if you're a

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[221] "China's Strategy in Djibouti: Mixing Commercial and Military Interests." Council on Foreign Relations
[222] Vorndick, Wilson. "China's Reach Has Grown; So Should the Island Chains." Asia Maritime Transparency Initiative. Center for Strategic & International Studies, October 22, 2018. https://amti.csis.org/chinas-reach-grown-island-chains/.
[223] Adegoke, Yinka. "A New $60 Billion Agency Is the Clearest Sign the US Is Worried about China's Africa Influence." Quartz Africa, October 14, 2018. https://qz.com/africa/1423506/china-africa-debt-us-will-invest-60-billion-overseas-to-beat-chin-at-development/.

government in Africa and want to build infrastructure before the next election you probably will still go with the Chinese."[224] Bigger and quicker? Perhaps more agile? The ease of doing business comes from the fact that relative to the United States, there is "no red tape with China, only red flags."[225]

The movement of China from East to West, demonstrates their ability to acquire resources to execute the Belt and Road Initiative strategy. In other words, China is able positioning itself well to convert power with greater ease by "decoupling" their economic dependence on the United States through investment in Africa. Furthermore, placing a military base in Djibouti gives China a boost in agility. First, it allows for China to surveille (sense) activities and intelligence from the United States. Second, the strategic location of China's base relative to Africa and the Middle East makes it significant. What then is the benefit to China moving East to West?

With the global economic center shifting gradually from both sides of the Atlantic to the Indo-Pacific region since the beginning of the 21st century, this part of the world has become the global production center and corridor or trade and energy, whose glue comes from the forces of economic globalization.

According to the United States Indo-Pacific Command (USINDOPACOM) Commander, Admiral Phillip Davidson, China is the number one strategic challenge to the United States for the twenty-first century.[226] Through a militaristic lens, USINDOPACOM views China's economic investment as one more sinister. That is, as an attempt to physically cut off allies and

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[224] Adegoke, Yinka. "A New $60 Billion Agency Is the Clearest Sign the US Is Worried about China's Africa Influence."
[225] Colloquialism used to describe the ease with which deals can be struck with China indicating that there is no red tape or bureaucracy holding up deals, rather there are red flags meant to refer to the Chinese flags that are often flown over Chinese built infrastructure in foreign, sovereign nations.
[226] Aitoro, Jill. "Adm. Davidson, Indo-Pacific Commander' 'We're Not Asking People to Choose between Us and China.'" Defense New. Reagan Defense Forum, December 11, 2019. https://www.defensenews.com/smr/reagan-defense-forum/2019/12/11/adm-davidson-indo-pacific-commander-were-not-asking-people-to-choose-between-us-and-china/.

partners of the United States through economic incentive and military seizure when loans from the Belt and Road Initiative cannot be repaid. China's investment strategy seeks to increasingly isolate the Pacific Island partners and allies from the United States by cutting off what is commonly referred to as the first island chain. [227][228]

While the amount of Chinese military and economic activity continues to incrementally increase in the Indo-Pacific, the United States and other nations have begun to take notice with increasing concern over the ease with which Beijing is able to convert power, exercise agility and execute rapid learning.

The United States Strategy

In November 2017, President Donald Trump presented his vision of a Free and Open Indo-Pacific at the Asia-Pacific Economic Cooperation (APEC) summit in Hanoi.[229] It is believed that President Trump sought to implement a reorienting of U.S. policy towards China through the Free and Open Indo-Pacific. In May 2017, then Secretary of Defense James Mattis retitled the United States Pacific Command to the Indo-Pacific Command.[230] The name change, though seemingly insignificant to most, signals a pivotal shift to the United States' recognition of the increasing connectivity between the Indian Ocean and the Pacific Ocean. In other words, China's interests are no longer bounded by the Pacific Ocean; instead, they now span the Indian Ocean too, as evidenced with the establishment of its first overseas base in Djibouti, Africa.

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[227] The island chain is a geographical security concept used to illustrate a defensive or offensive perimeter by linking island sand other larger land masses together. Since American military planners int eh 1940s identified the initial chain as a means to secure the Soviet Union's and People's Republic of China's maritime approaches, the number of chains has grown to three. John Foster Dulles is attributed with designating the islands stretching from the Kurils, the Japanese home islands, and the Ryukyus to Taiwan, the Philippines, and Indonesia as the "first island chain" in the 1950s.

[228] Vorndick, Wilson. "China's Reach Has Grown; So Should the Island Chains." Asia Maritime Transparency Initiative. Center for Strategic & International Studies, October 22, 2018. https://amti.csis.org/chinas-reach-grown-island-chains/.

[229] Heiduk, Felix, and Gundrun Wacker. "From Asia-Pacific to Indo-Pacific" Significance, Implementation and Challenges, January 7, 2020. https://doi.org/10.18449/2020RP09

[230] Vorndick, Wilson. "China's Reach Has Grown; So Should the Island Chains."

Shortly thereafter, the notion of a Free and Open Indo-Pacific has shown up in various official, U.S. government documents. The White House National Security Strategy, United States Department of Defense, the State Department, and the Department of Commerce have all published or referred to the Free and Open Indo-Pacific in their respective doctrine. Most recently the Biden administration puts the Indo-Pacific front and center in terms of diplomacy. Signaling its commitment to multilateralism, the first commitment of the Biden administration was the Quad summit with the leaders of Japan, Australia, and India. Additionally, the first international visits for the United States' Secretary of State and Secretary of Defense were to Japan, the Republic of Korea, and India.[231]

According to Richard Maude, the Executive Director of the Policy at Asia Society Australia and a Senior Fellow at Asia Society Policy Institute, asserts that the Biden administration is also revieing the distribution of its military forces and U.S. supply chain security and has kept the Trump administration's tariffs for the time being. Overall, President Biden's administration seeks to "competitively coexist" with China highlighting areas such as economics, politics, security and technology as focal points.

The People's Republic of China

As the previous section laid out, President Xi Jinping's Belt and Road Initiative describes China's foreign policy pursuits, not just heading west, but also its pursuits towards the west. As Professor T.V. Paul, RISS Visiting Professor and James McGill Professor of International Relations suggests, "that although asymmetrical for now, Beijing is pursuing power transition and military build-up with the intentional of replacing the US as the dominant power in the Indo-pacific region. Towards this end, Beijing is using the economic strategy of the Belt and Road

[231] Maude, Richard. "The Biden Administration and the Indo-Pacific." Asia Society.org. Asia Society, April 7, 2021. https://asiasociety.org/australia/explainer-biden-administration-and-indo-pacific.

Initiative (BRI) and massive foreign direct investment in different regions to develop commercial and trading networks."[232] Professor Paul also astutely points out how China is able to accomplish this when he writes, "China has adopted two of the three components of liberal peace-economic interdependence and international institutions-while abandoning the democratic component."[233]

The One Belt, One Road 2015 Visions and Actions document released in 2015 outlines, the pillars of the Belt and Road Initiative including policy coordination, connectivity of institutions, trade connectivity, financial integration, and people-to-people links, all exercised through economic interdependence and international institutions without the democratic component.

THE UNITED STATES VERSUS CHINA IN THE INDO-PACIFIC

How does the United States fare vis a vis China in the Indo-Pacific? While the United States caught in entanglements in the Middle East for the past decade, China is actively seeking to establish a greater regional presence both in and beyond the South China Sea. To accomplish this, China must obtain a military base in the Pacific in order to connect with its many ports in Africa. As the 2015 Chinese Military Strategy White Paper illustrates, Beijing has a plan to develop a blue-water navy fleet. That is one that is able to carry out operations for offshore protection, thus highlighting the importance of moving from one maritime theater of operation (the Pacific Ocean) to two (the Pacific and the Indian).[234] While Vanuatu is frequently identified as the most likely candidate where China could establish a permanent military presence, other

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[232] Hussain, Nazia. "The Rise of China and the Emerging Order in the Indo-Pacific Region." S. Rajaratnam School of International Studies. Nanyan Technological University, March 8, 2019. https://www.rsis.edu.sg/rsis-event-article/rsis/the-rise-of-china-and-the-emerging-order-in-the-indo-pacific-region/.
[233] Hussain, Nazia. "The Rise of China and the Emerging Order in the Indo-Pacific Region."
[234] Miracola, Sergio. "The Indo-Pacific 'Encirclement': How Is China Reacting?" ISPI Online. Instituto Per Gli Studi di Politica Internazioale, June 4, 2018. https://www.ispionline.it/it/pubblicazione/indo-pacific-encirclement-how-china-reacting-20716.

Pacific states such as Tonga have also been mentioned, and in the West, China owns many ports such as the one in Djibouti in the Horn of Africa, Gwadar in Pakistan, Hambantota in Sri Lanka and in the Maldives and in Tanzania. [235] First, China needs to protect its supply routes for economic development, in other words their sea lanes of communication. Two, these routes enable naval military growth while minimizing its maritime vulnerability.

China has been slowly exploiting the vacuum created by a withdrawal of U.S. influence not only in certain regions of the world such as the Indo-Pacific but within international institutions, too. For example, China has been positioning its diplomats within U.N. agencies, slowly shaping institutions to reflect its interests. Moreover, China follows one of the central tenants of designing antifragile systems by ensuring that they have developed redundancy and overcompensation in trying to achieve their influence. Not only does China seek to influence the upper echelons of world leaders and governments through involvement in international institutions, but China also considers the people residing within these nations, paying particular attention to the Chinese diaspora communities in colleges. Confucius Institutes and local newspapers serve as a way for "Beijing to spread propaganda under the guise of teaching, interfere with free speech on campuses and even spy on students."[236]

Watching the empires of Europe collapse, the rise and fall of the Soviet Union, and the ascent of the United States to the top of the international political order post World War I, China has learned by watching other nations struggle. In particular, the collapse of the Soviet Union undoubtedly left a lasting impression on China. As David Goldman wrote,

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[235] Citowicki, Philip. "China's Reach Tests the Pacific's Fragile Island Democracies." Foreign Policy, January 7, 2020. https://foreignpolicy.com/2020/01/07/chinas-reach-tests-the-pacifics-fragile-island-democracies/.
[236] Jakhar, Pratick. "Confucius Institutes: The Growth of China's Controversial Cultural Branch." BBC News, September 7, 2019. https://www.bbc.com/news/world-asia-china-49511231.

> China thinks that power is the arbiter of world affairs, and that technology is power. That's something it learned from Ronald Reagan. He won the Cold War with a military buildup that catalyzed an economic revolution. Military research and development produced countless inventions of the Digital Age, from fast and cheap microchips to the internet. The Soviet Union folded in the face of America's superior arms and entrepreneurial growth. China watched and learned.[237]

Here, learning has become a central tenant of the success in China. However, what is noticeably absent from China's recent history is its own recent experience in conflict.

In the absence of this experience, China has tried to compensate by close study and analysis of other nations' wars. In particular, studying the wars of the United States.[238] As was mentioned earlier in the chapter, China was greatly influenced by the military might of the United States during the first Gulf War and how it overwhelmingly defeated the Iraqi Army. This jumpstarted China's own military modernization efforts. But it should be noted that reading about combat and experience in combat are two different things. Taleb does not mention historical knowledge of shocks as one of his characteristics of antifragility. He mentions a history of experiencing past shocks. That is, an experience with or exposure to shocks.

While many have focused on China's measures of hard power, it is the development and refinement of their soft power that is equally concerning. According to Richard Herr of the Australian Strategic Policy Institute (ASPI), "China reportedly has been spending an estimated

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[237] Goldman, David P. "What China Learned from Cold War America." Wall Street Journal, July 24, 2020. https://www.wsj.com/articles/what-china-learned-from-cold-war-america-11595618253.

[238] Cheng, Dean. Edited by Andrew Scobell, David Lai, and Roy Kamphausen. *Strategic Studies Institute, US Army War College*, November 1, 2011, 153–200. http://www.jstor.org/stable/resrep11966.8.

US$10 Billion annually for over a decade to promote its soft-power message globally.[239] Additionally, as a way of developing soft power "China has increasingly embraced hybrid military-humanitarian missions that could become more prominent as the US war efforts in Iraq and Afghanistan wind down."[240] Since its conception in 2008, China has launched the ship, "Peace Ark," which China's People's Liberation Army operates. In the past, the American hospital ship, the USNS Mercy, has been sent to Asia to take part in disaster relief operations.

As Philip Citowicki states, "China is acutely aware that the fledgling democracies of the Pacific are prone to shortsightedness-and in some cases outright corruption-and, as a result are at risk for manipulation that goes against their best interest."[241] Amassing resources with the strategy, China's ability to convert power is one of the reasons it has risen to a position of global prominence today. China began with economic integration in the global economy and then began amassing resources in order to exert its will on states in the region. Starts locally and then spreads globally.

With respect to agility, "China's diplomatic statecraft has taken leaps and bounds over the past decade. Beijing has become increasingly adept at working with and messaging international institutions to support and legitimize its actions."[242] It does particularly well in the Indo-Pacific, particularly with the Pacific Island nations. China senses a gap, vacuum, or misstep by the United States in the region and quickly pivots to respond to those issues. For example, in a Professional Academic Development Speaker Series event at the United States Indo-Pacific

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[239] Herr, Richard. "The Role of Soft Power in China's Influence in the Pacific Islands." The Strategist. Australian Strategic Policy Institute, April 30, 2019. https://www.aspistrategist.org.au/the-role-of-soft-power-in-chinas-influence-in-the-pacific-islands/.
[240] "How China Mimics US Soft Power." The Diplomat, November 9, 2010. https://thediplomat.com/2010/11/how-china-mimics-us-soft-power/.
[241] Citowicki, Philip. "China's Reach Tests the Pacific's Fragile Island Democracies." Foreign Policy, January 7, 2020. https://foreignpolicy.com/2020/01/07/chinas-reach-tests-the-pacifics-fragile-island-democracies/.
[242] Citowicki, Philip. "China's Reach Tests the Pacific's Fragile Island Democracies." Foreign Policy, January 7, 2020. https://foreignpolicy.com/2020/01/07/chinas-reach-tests-the-pacifics-fragile-island-democracies/.

Command, Dr. Anna Powell commented that "when addressing the people of the Pacific Island nations the United States often refers to the region as Oceana, a name fervently rejected by the local populous. When it comes to China, they don't make those mistakes."

Recently, the government of Solomon Islands decided to sever ties with Taiwan in favor of the People's Republic of China. Shortly thereafter, Kiribati broke ties with Taiwan too. In a few short days, Taiwan's support from Pacific countries was reduced by one-third, demonstrating China's resolve to marginalize diplomatically.[243]

"The Chinese puzzle thus defies commonly-held dichotomies in the social science literature: socialist versus capitalize social systems, planned versus market economy, public versus private ownership, and authorization versus democratic rule. In today's China, one finds elements of all these binary opposites coexisting side by side."[244]

MODEL VALIDATION: CHINA IN THE INDO-PACIFIC

Examining the case study of China in the Indo-Pacific, parameters from the case study were translated into the model to represent the conditions for China during this time (Table 34). Additionally, environmental conditions are captured in Table 35.

Table 34: Agent Initialization Conditions (China post-Maoist Revolution)

Variable	**Parameter Value(s)**
Performance	20
Capacity	4
Agent Type	Resilient
Percent-Learn	0.21
Percent-Forget	0.01
Recovery Time	3

[243] Pryke, Jonathan. "Solomon and Kiribati Snub: Taiwan for China-Does It Matter?" The Lowy Institute, September 23, 2019. https://www.lowyinstitute.org/the-interpreter/solomons-and-kiribati-snub-taiwan-china-does-it-matter.
[244] Feng, Wang, and Yang SU. "1989: Twenty Years After." Irvine, CA, 2009.

Table 35: Environment Initialization Conditions

Variable	**Parameter Value(s)**
Gamma Mean	5
Gamma Variance	5
Number of Shocks	46

To translate the historical narrative to that of the model, China (the agent) given an initial *performance* value of 20. This is an appropriate value given that China had just emerged from the volatility of the Maoist Revolution. As a result, the initial capacity was set to a value of 4, rendering the agent as resilient at the start of the simulation.

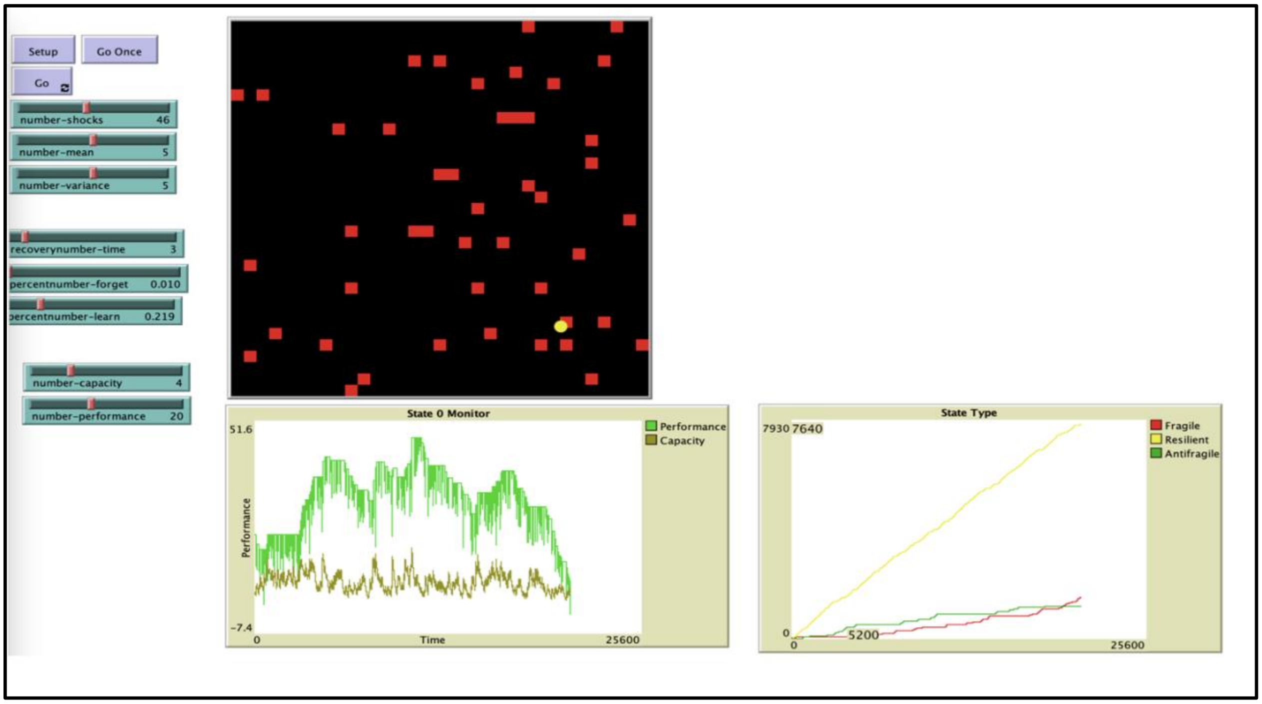
The *number of shocks* was set to 46 as a number that is close to but smaller than those in the next simulation run where the United States is the agent. The justification for this is because, during this time, China experienced very few direct shocks; however, they benefit from friction of other nations, such as the United States, as evidenced by their rapid military modernization efforts that were inspired by the United States during the first Gulf War.

The percent-learn variable was set to a value of 0.21, and the percent-forget variable was set low to a value of 0.01. The reason for the low level of forgetting is due to the nature of China's governance regime. As a highly centralized system of governance, the regime is very controlled with very few mouthpieces, leaving little room for stray from the central narrative because it is so tightly controlled. That is to say, there is one narrative, the Chinese Communist Party's narrative, that is not deviated from. Conversely, the high level of learning China has exhibited emanates from its rapid rise to prominence in the international political order through its rapid military modernization and economic rise; thus, China's ability to learn from its experiences and the experiences of others has rendered a high level of learning. The *gamma* *mean* and *gamma variance* variables were set to a values of 5. Finally, the recovery time variable was set to a value of 3, indicating a relatively quick recovery time. For this run, the terminating condition was occurred when the performance equaled a value of 0.

Figure 36 provides a graphic of the output from the simulated run. Tracing the State 0 Monitor graph, one can see that China emerges from the volatility of the Maoist Revolution resilient. The environment in which China enters into is one that has very few shocks, and in fact, China has no direct experience with shocks. Rather, China benefits from the other's experiences with shocks, specifically as it relates to their rapid modern militarization. Despite the low number of shocks, China is able to hit a trajectory that allows it to become antifragile for a period of time; however, as the State Type Graph demonstrates, China will eventually spend most of its time in a state of resilience and not antifragility.

The behavior in this scenario indicates that China is headed for a deterioration in performance in the future. Upon re-examination of Taleb and Treverton's characteristics of fragility and antifragility, China's behavior in this simulation seems to confound their tenants of antifragility causing a decline in performance. For example, China's lack of direct experience with shocks could be one plausible explanation for the decline in performance. In future extensions of the model, it may be beneficial to distinguish direct learning from indirect learning, as China seems to display the latter based on its lack of history of experiencing shocks directly. Additionally, China's governance regime is one that is highly centralized and not diversified. As discussed earlier, this has led China to have a lower forgetfulness value, something which Taleb and Treverton had not considered. Overall, the governance type and lack of experience with shocks are plausible explanations for the decline in performance of China over time.

Figure 36: China's Behavior Post-Maoist Revolution



MODEL VALIDATION: THE UNTED STATES 1991-PRESENT

Examining the case study of China in the Indo-Pacific, parameters from the case study were translated into the model to represent the conditions for the United States during this time (Table 36). Additionally, environmental conditions are captured in Table 37.

Table 36: Agent Initialization Conditions (United States)

Variable	**Parameter Value(s)**
Performance	40
Capacity	15
Agent Type	Antifragile
Percent-Learn	0.07
Percent-Forget	0.06
Recovery Time	3

Table 37: Environment Initialization Conditions

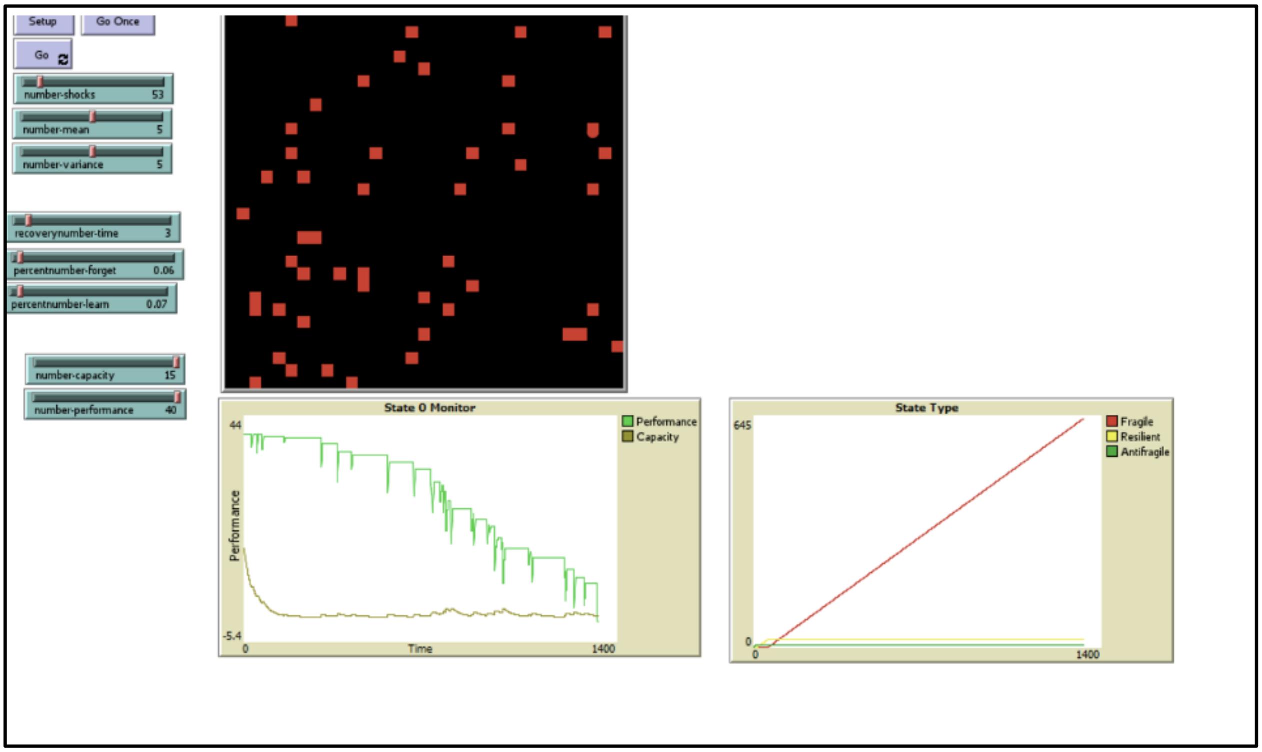
Variable	**Parameter Value(s)**
Gamma Mean	5
Gamma Variance	5
Number of Shocks	53

To translate the historical narrative to that of the model, the United States (the agent) was endowed with a value of 15, rendering it initially antifragile. The initial *performance* of the agent was set up given a value of 40, very high, giving it was coming out of a resounding success in the first Gulf War and the end of the Cold War. The recovery time the agent was endowed with was set as a value of 3. The percent-learn variable was set to a value of 0.07, and the percent-forget variable was set to a value of 0.06. The critical element here is the percent-forget variable. One of the challenges for the US, as discussed above, has been learning about rising threats, and developing coherent policy responses to them. This relatively high forgetting parameter reflects this challenge: a tendency not to effectively develop and follow through strategy to maintain the antifragility capacity initially possessed.

During this same time, the United States would experience a moderate number of shocks in the environment from the bombing of the USS Cole in the Gulf of Aden to the Battle of Mogadishu in Somalia to the United States' involvement in the Kosovo War. To model this, the *number of shocks* was set to 53. The *gamma mean* and *gamma variance* variables were set to a value of 5. The terminating condition for the simulation is when the simulation gets to 2000 tics.

Figure 37 provides a graphic of the output from the simulated run. Tracing the State 0 Monitor graph, one can see that the United States was living in a relatively sparse but large shock world. Over time, however, the United States became fragile over time with respect to the great power competition emerging with China due to relatively few opportunities to learn, and a rapid forgetting.

Figure 37: The United States (1991-2000)



CONCLUSION

China's economic rise and rapid military modernization have certainly made the United States' role in the Indo-Pacific less certain. China has developed a stealth fighter, built its own supercarriers, and exceeded the United States in critical technologies. Through its Belt and Road Initiative, China seeks to make its economy less dependent on exports to the West. As Colonel Wesley Hallman (ret.) writes, "China's real focus is its aggressive challenges of America's true source of strength-our dynamic economy. Through strategies including Made in China 2025, an industrial policy of aggressive cybertheft, predatory investment strategies and forced intellectual property transfer for access its domestic market, China advanced." On top of all this, China's centralized governance structure and ability to make timely decisions, seems to work in China's favor. However, when these two converge, it can be revealed that China's Belt and Road Initiative is tied to its massive debt, more than 250% of GDP.[245] This excessive debt is a weakness in China's great power competition in the Indo-Pacific.

However, China's lack of experiencing past shocks holds problematic implications for its future ability to deal with stress. While the United States and the rest of the world took on the stresses brought by the War on Terror, China used this time to jettison its policy of the "peaceful rise of China." Seizing South China Sea reefs to build militarized outposts and gain footholds in the world's busiest shipping lanes went mostly unchallenged. As the results of the model suggest learning and history of surviving past shocks matter in the pursuit of becoming antifragile. The implications are such that that China's lack of history with experiencing past shocks may render them less antifragile than perceived when it comes to a conflict with the United States. The absence of these external tests, China has limited experience with a specific type of learning, experiential learning, in which an entity learns by doing.

[245] Wu, Jin. "China's Debt Problem." Reuters. Accessed 2021. http://fingfx.thomsonreuters.com/gfx/rngs/CHINA-DEBT-HOUSEHOLD/010030H712Q/index.html.

CONCLUSION

The purpose of this dissertation is to understand *why some states are more antifragile than others, and what difference antifragility makes*. By identifying where the concept of antifragility would best fit into the scholarship of International Relations, a theoretical home was found within the construct of the Realist paradigm. By developing three propensity variables of state fragility/antifragility, the five characteristics of fragile/antifragile states according to Nassim Taleb and Gregory Treverton were enhanced. Inspired by Johnson and Gheorghe's system dynamics model on antifragile systems of systems, an agent-based model of state antifragility was created, whose purpose was to help us better understand how states become fragile or antifragile.

The model focused on the two core concepts of state antifragility- the three main characteristics states possess that move them along the spectrum of fragility and the shocks they interact with in the international environment. Rather than try to capture every granular detail of state antifragility, this model serves as a theoretical proof of concept that is purposefully simplistic in its design so that others may enhance the model later to gain greater insights into antifragile states.

The static model analysis in World A focused on providing insights into how antifragility is important for state survival and is a static model in which capacity is fixed: states neither learn to be antifragile nor forget and cease to be antifragile. That is, their *percent-learn* and *percent-forget* variables were set to 0, and the state simply ran into shocks and remained fixed as either fragile, resilient, or antifragile.

The dynamic model runs in World B examined what kind of world is going to be best for state survival and maintaining antifragility, and in this model state capacity did not change: states can ‘learn’ to have a higher capacity and become (more) antifragile, and they can forget their existing capacity and become (more) fragile. That is, the agent’s *percent-learn* and *percent-forget* variables are greater than 0.

The results of the experiments yielded several nonlinear key results of numerous independent variables with respect to life length, initial performance, recovery time, and the number of shocks in the environment. For example, in both World A and World B, an increase in recovery time results in a decrease for all state types, with an interesting observation in World B: antifragile states actually increase their life length in the recovery time range of 7 to 11. With respect to an increase in the number of shocks in the environment, all states experience a decrease in their life length, except for at the 75-shock value in World B. Here, all states begin to experience an increase in their life length with an increase in the number of shocks in the environment.

Additionally, the results from World B reveal that portion of time a state spends being antifragile increases with respect to an increase in recovery time; thus, states are not forgetting while they are recovering and are able to maintain their antifragility. A similar behavior is observed when examining an increase in the number of shocks in World B. The portion of time a state spends being antifragile increase with respect to an increase in the number of shocks, demonstrating that the how the antifragile gains from volatility (Taleb and Treverton, 2015).

The model’s results suggest that in a world defined by anarchy, perhaps excessive tempering anarchy is not the best strategy if a state seeks to be antifragile. That is, embracing some degree of volatility and randomness while focusing on the development of learning, power conversion, and agility is necessary in order to become antifragile. This is not to say that states should throw themselves at every potential shock the world provides them. Instead, states should seek to design their governance structures, institutions, and economies such that they are able to improve from ongoing experience with the stress of the international environment. To do so, however, requires a self-awareness of beliefs and mental models that may have inadvertently prevented this design from coming to fruition.

The model's simplicity and genericism were intentional design choices. First, the model serves as a theoretical one in which prediction of future outcomes is not the main goal. To my knowledge, this is the first attempt at modeling state antifragility. The notion of antifragility is applicable to wide range of topics within international relations including foreign policy, conflict and cooperation, global health and international political economy and development. It is my hope that this model serves as the foundation for future work on antifragility in international relations to help address some of our most pressing challenges as the implications of this work span beyond modeling and simulation.

IMPLICATIONS

There are two primary implications for this work with regard to the field of International Relations. First, the research presented in this dissertation, provides a methodological and conceptual contribution to International Relations by enhancing the current measures of fragility/antifragility. The three propensity variables will hopefully help drive the conversation within International Relations to examine and consider factors internal to states such as agility and learning which the model suggests can have major implications for the development and maintenance of state power. The result of this process could allow for us to anticipate who could be "winners", "losers" and "sleeper states" in the next global shock which in turn could alter how we think about power-politics, political world order, and security.

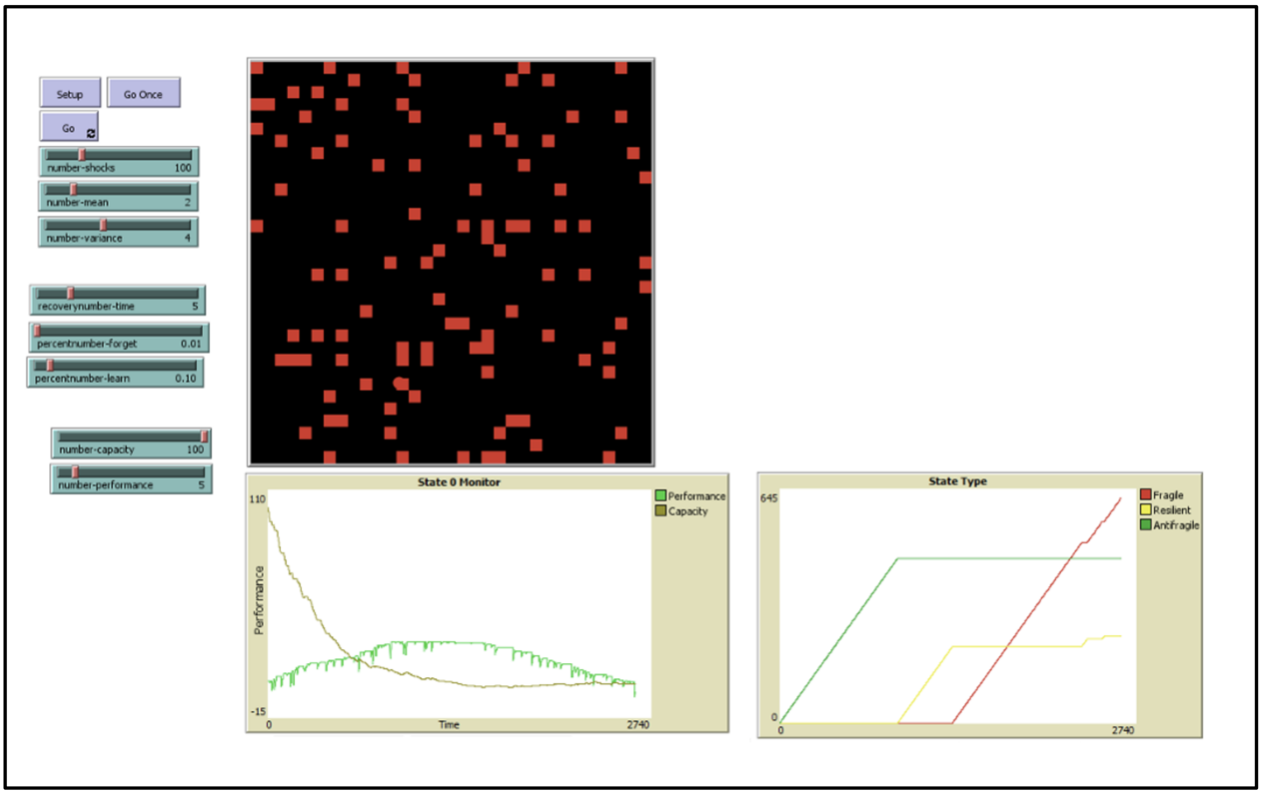
Second, state antifragility could provide a blueprint for creating, organizing, and structuring state/international institutions. Understanding what is needed to achieve antifragility at the state level of analysis can allow others to abstract further out and apply this architecture to international institutions and organizations. Conversely, the antifragile architecture could be decomposed further and applied towards governance systems, potentially calling into question the efficacy of the state construct in favor or a more antifragile one.

Case Studies

The case of the United States during the first and second Iraq War revealed the importance of the rise of non-state actors in the international sphere. Specifically, the simulation model run presented in Chapter 6, revealed the importance of learning by Al Qaeda and the United States. Prior to the September 11, 2001, attacks by Al Qaeda on US soil, Al Qaeda had spent roughly twenty years introducing smaller-scale shocks into the international environment in order to observe the responses from their adversaries. This virtue of volatility allowed Al Qaeda to learn and adapt their strategies over time, all culminating in the attacks on September 11, 2001.

As the United States entered the war in Iraq, a traditional military victory was easily achieved in the ousting of Iraq's leader, Sadaam Hussein. What caught the United States flat footed was the disenfranchised Sunni majority, who formed what would become known as Al Qaeda in Iraq. This franchising effect of Al Qaeda into a formal insurgency within Iraq, exposed the lack of learning the United States underwent during the Vietnam War fighting insurgencies along with an inability to be agile against a new, non-traditional enemy. Al Qaeda in Iraq successfully outmaneuvered the United States military until the United States, through the leadership of General Petraeus, changed strategies and provided a surge of troops in 2007, highlighting the key component of having a strategy as a part of power conversion. That is to say, that the United States possessed more resources than Al Qaeda in Iraq during this time, but without a proper strategy to effectively utilize those resources it was all for not, until a strategy emerged in 2007.

Figure 38: Evolutionary Behavior of Al Qaeda in Iraq during the Iraq War (2003-2010)



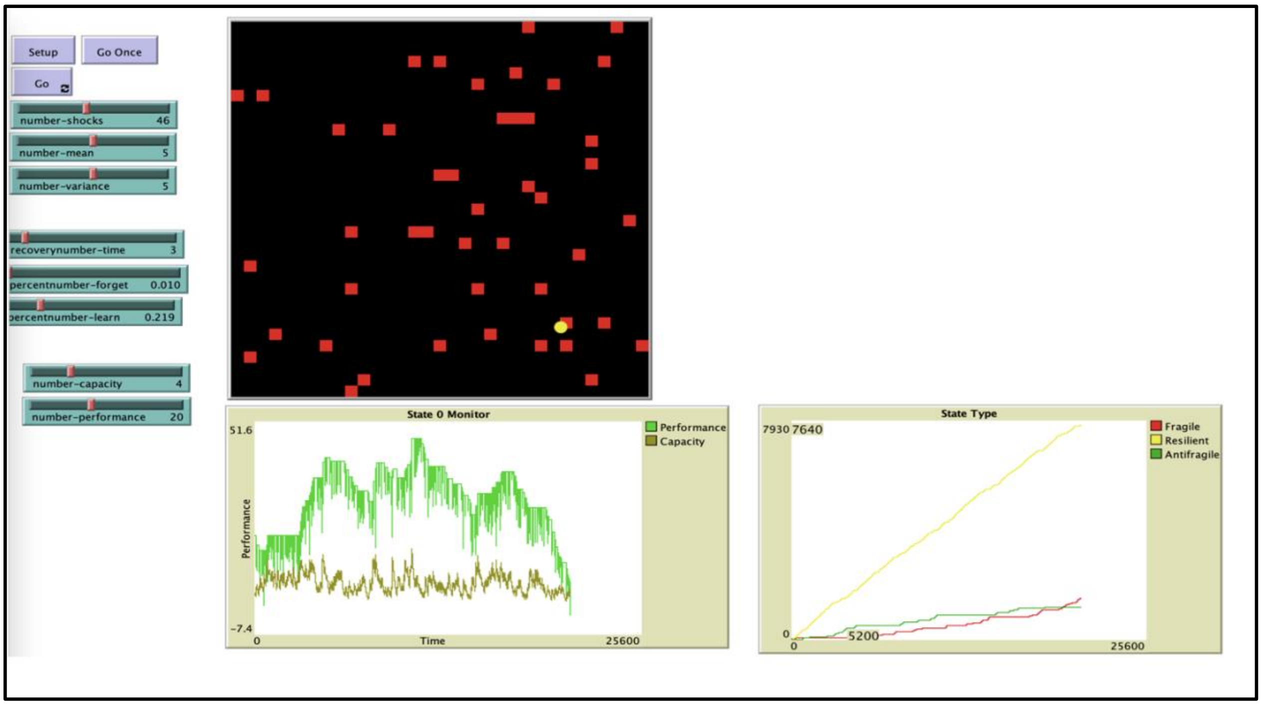
The legacy of this example is one that continues to be seen today, as a new non-state actor has emerged. Though presently ISIS is also largely defeated, their high ability to learn and adapt remains a potential threat in terms of proliferating its ideology and executing its strategy of establishing a Caliphate.

China's rise in the 20th century to become a regional hegemon is an interesting puzzle whose outcome has yet to be determined. It's rapid ascent into the political international order demonstrates its ability to quickly learn, adapt and respond (agility), and amass power (primarily resources). China demonstrates that it is learning the lessons of history, specifically as it pertains to behavior and experiences of Soviet Union during the Cold War. While the Soviet Union violently and publicly quelled protests of its communist rule, China responds to their own internal dissent through means of constant pressure rather than decisive campaigns in order to not trip international taboos about their means of repressing internal dissent. Through its Belt and Road Initiative and then military modernization inspired by the United States' performance in the first Gulf War, China, on paper, has the three key variables necessary to become antifragile; however, what remains to be seen is how it's internal volatility and the consolidation of autocratic rule in place of the party oligarchy will erode those three propensity variables.

First, though China has recovered well from the volatility of the Maoist period, it has yet to experience any direct shocks since this time almost four decades ago. The Chinese Communist party lacks this critical variable of having history surviving past shocks, and instead, serve as the recipients of the friction of the United States. That is to say, China benefits from the shocks the United States experiences, whether that is through observation of the First Gulf War that led to China's modern militarization campaign, or through more direct means of stealing intellectual property to develop highly capable weapons systems and technology. Without the direct experience and knowledge that experiencing volatility brings, China's indirect experiencing shocks by extrapolating the benefits of shocks from others may not lead to antifragility.

Another key component that signals China may be in trouble is found it it's leverage ratio, which fell by 2.6 percentage points.[246] Additionally, China's debt-to-GDP rose significantly from 259% to 285% in 2020.[247] China's dependency on exports to the west, coupled with its centralized government create burdens for China that may accumulate over time and prove too much for the communist nation in the long run.

Figure 39: China's Behavior Post-Maoist Revolution



[246]Liu, Lucille, and Douglas Huang. "China Leverage Ratio Falls as Government Tries to Rein in Risk." Bloomberg News, May 1, 2021. https://www.bloomberg.com/news/articles/2021-05-01/china-leverage-ratio-falls-as-government-tries-to-rein-in-risks.
[247] Mohi-uddin, Mansoor. "Stabilising China's Leverage Ratio." Bank of Singapore, April 1, 2021. https://www.bankofsingapore.com/research/stabilising-china-leverage-ratio.html.

Managing Antifragile Adversaries

In the early pages of Dumas' classic, The Three Musketeers, the protagonist D'Artagnan is urged by his father to fight as often as possible. Such advice would make no sense if one considered the young hero of the story to be at risk of injury, death, or dismemberment. And yet it has a certain logic to it. It is through his pursuit of fights wherever possible that he meets his friends, develops his skills, identifies, and creates his enemies, and ultimately achieves his ambitions. The advice makes sense in the context of the concept of antifragility. If D'Artagnan is antifragile then he should indeed seek out opportunities for combat. It is through such combat that he will develop and sharpen his skills to become a "musketeer." D'Artangian in Dumas' novel is antifragile because his losses are relatively rare and the payoff losses typically modest. His wins are more frequent, and the payoff gains larger. He learns and develops his agility, power, and strength through his adventures and experience.

One of the key implications for this study involves the ways in which states should think about antifragility in their relations with each other. This section identifies the problem of the antifragile adversary, shows how in the face of such an adversary deterrence is particularly difficult, and explores strategies one might pursue in the face of such an adversary in order to deter, contain, or defeat states that either are – or believe themselves to be – antifragile.

Antifragiles thrive in a world of randomness and most importantly gain from disorder. It is therefore challenging to deter an antifragile adversary. For instance, if the penalties and sanctions imposed upon Putin by the West make his position in Russia more secure and help him achieve his goals, then Putin is unlikely to be dissuaded from additional poisonings, election manipulation campaigns, territorial aggressions, and other manifestations of Russian "hybrid warfare" doctrine by the threat of punitive measures from which his regime suffers relatively little and derives some benefits. If Putin's regime is indeed antifragile with respect to moderate conflict with the West, then what? It is critical to identify means by which the antifragile adversary can be deterred from aggression, contained, or defeated.

The simplest intuition about deterrence is that it is simply about credibly threatening large enough costs that the adversary is dissuaded from taking a risk. But this strategy is sometimes difficult to implement against an anti-fragile adversary. If the structure of their payoff function is such that they will ultimately benefit from conflict, threatening conflict will hardly dissuade.

Consider the following three model runs. The state being modeled is very antifragile initially and has a high level of performance relative to the mean shock (Table 38 and Table 39). If nothing changes, this state will likely keep growing stronger, as shown in Figure 40.

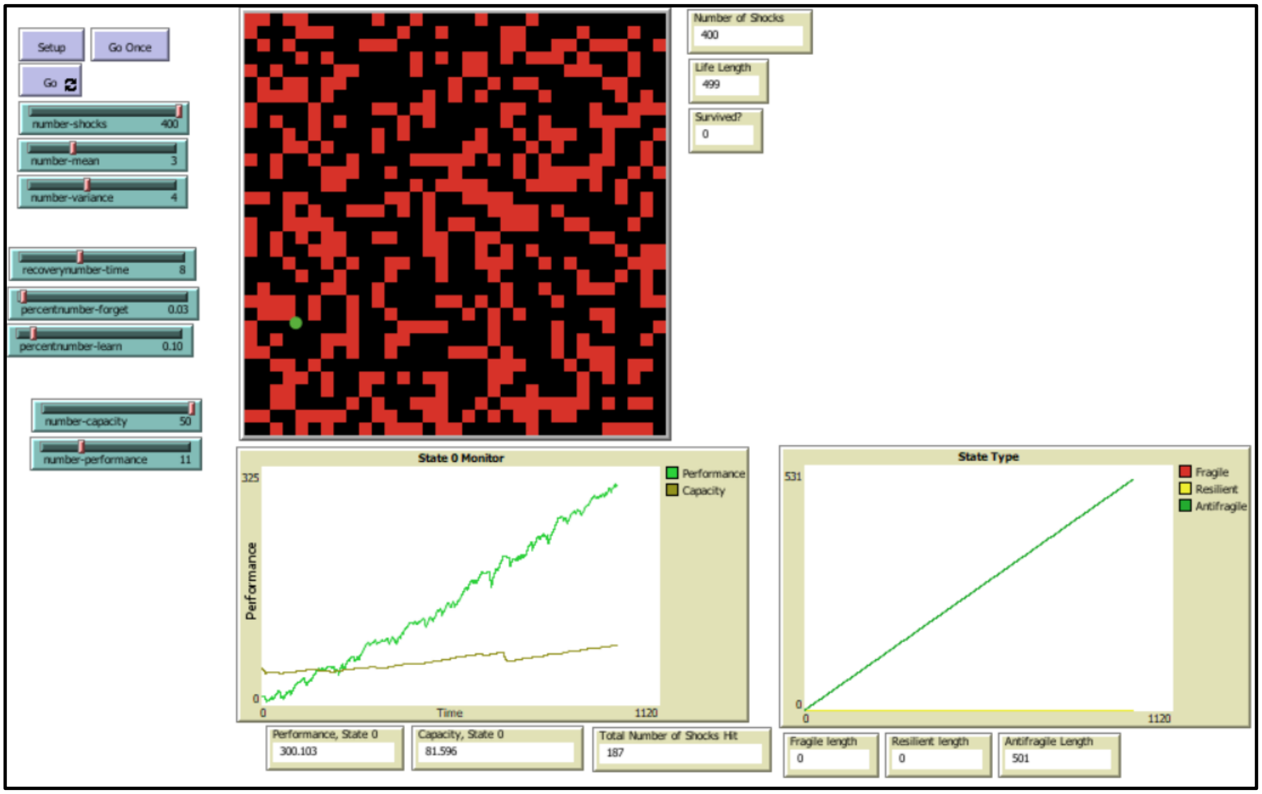
Table 38: Agent Initialization Parameters

Variable	**Parameter Value(s)**
Performance	11
Capacity	50
Agent Type	Antifragile
Percent-Learn	0.10
Percent-Forget	0.03
Recovery Time	8

Table 39: Environment Initialization Conditions

Variable	**Parameter Value(s)**
Gamma Mean	3
Gamma Variance	4
Number of Shocks	400

Figure 40: Antifragile State with High Level of Performance Relative to Shock Mean



What might be done? One surprising partial solution is actually to take away shocks from the state (Table 41). With all other parameters kept constant, the state transitions to become fragile with these parameters simply because it faces fewer shocks (Table 41 and Figure 41).

Table 40: Agent Initialization Parameters

Variable	**Parameter Value(s)**
Performance	11
Capacity	50
Agent Type	Antifragile

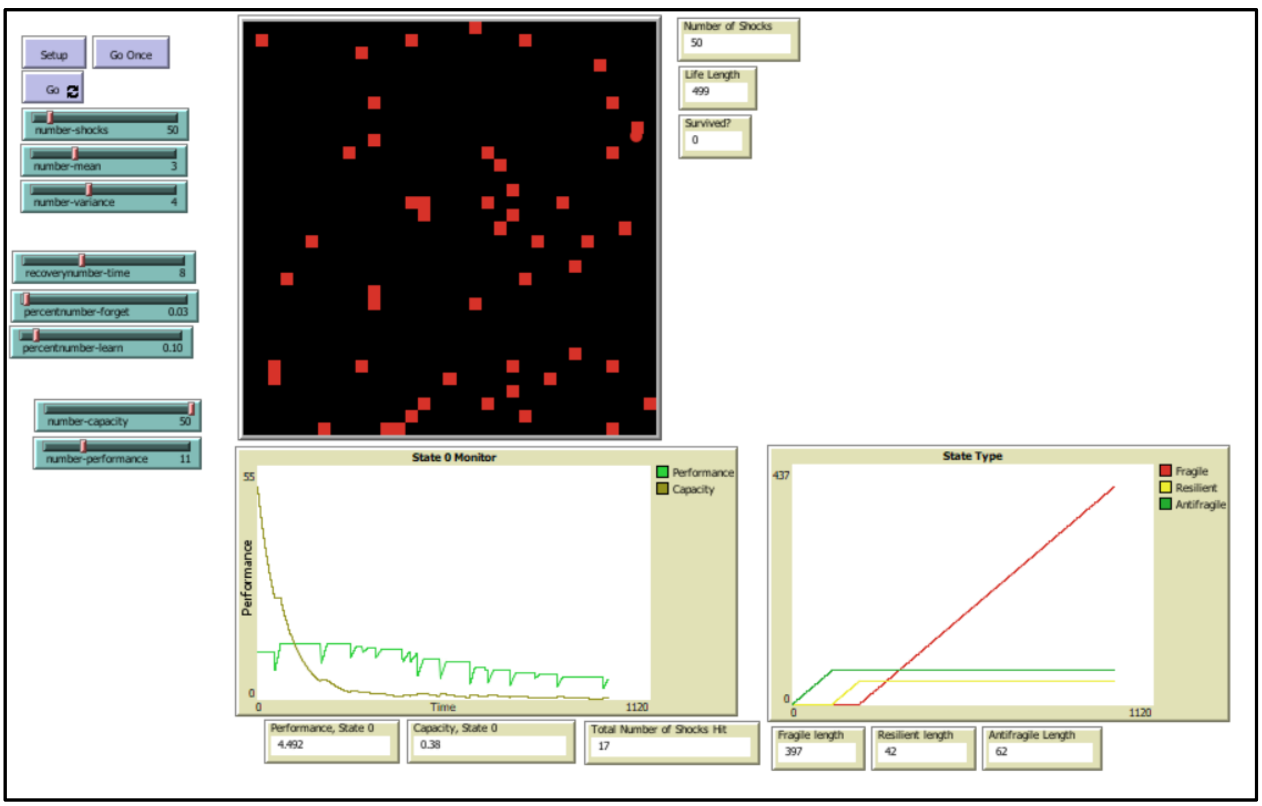
Table 40: Continued

Variable	**Parameter Value(s)**
Percent-Learn	0.10
Percent-Forget	0.03
Recovery Time	8

Table 41: Environment Initialization Conditions

Variable	**Parameter Value(s)**
Gamma Mean	3
Gamma Variance	4
Number of Shocks	50

Figure 41: Antifragile State with High Level of Performance Relative to Shock Mean with Fewer Shocks



Even better is to reduce the number but increase the severity of the shocks (Table 43 and Figure 42).

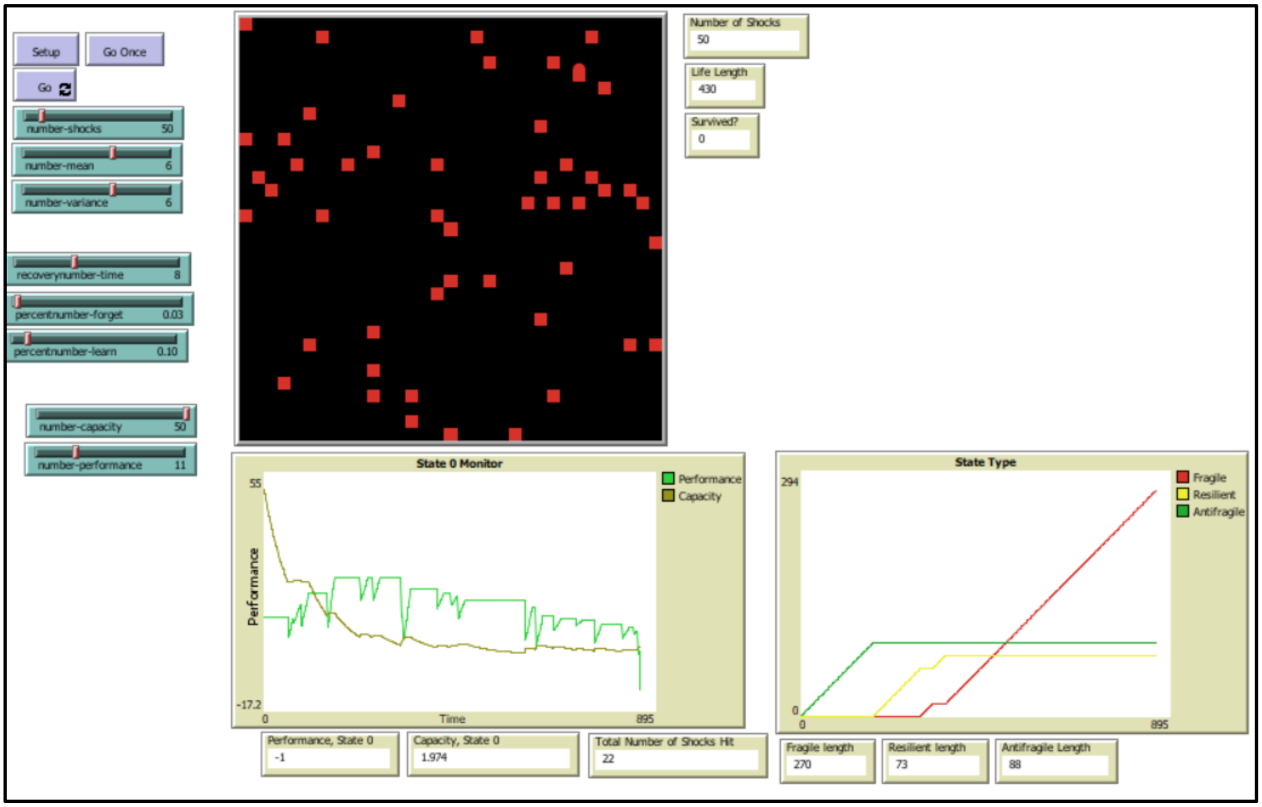
Table 42: Agent Initialization Parameters

Variable	**Parameter Value(s)**
Performance	11
Capacity	50
Agent Type	Antifragile
Percent-Learn	0.10
Percent-Forget	0.03
Recovery Time	8

Table 43: Environment Initialization Conditions

Variable	**Parameter Value(s)**
Gamma Mean	6
Gamma Variance	6
Number of Shocks	50

Figure 42: Reduced Shock Severity



Frequent but targeted penalties may be required. Frequency and severity together are important and potentially effective in deterring an antifragile adversary.

Alternately, an important strategy could be a search for the areas and aspects in which the putatively antifragile regime is in fact fragile. Where are its vulnerabilities? Is there propaganda, economic, cyber, or territorial weaknesses that can be exploited in ways that truly weaken the regime – that bypass and undermine the aspects its position which are antifragile?

If this is not a viable strategy, then strategies that cope with the aspects an opponent's regime that are anti-fragile over a longer time horizon are necessary. One key is to develop ideas and responses that make one's own side more anti-fragile. An initial first step involves moving beyond the emphasis on resilience discussed in the literature review to more emphasis on capacity to come back better from challenges.

FUTURE MODEL MODIFICATIONS

As with all models and simulations, there are infinite possibilities for designing and constructing a model. The best ones, however, are the simplest ones which capture the basic components of the behavior and structure you are trying to model. Modifications made to this model provide us with greater fidelity of the system being modeled.

Agent Enhancements

With respect to the agents in this model they are meant to represent states at their core with each possessing a capacity compromised of agility, learning and power conversion. Though this model version did not explicitly model the three propensity variables, a future version whereby the three propensity variables are directly modeled is an example of how the model might be extended. Additionally, variables that were discussed in great detail such as agility should be decomposed into its aggregates-sensing and responding in the case of agility- in order to have greater fidelity. Similarly, power conversion should also be aggregated into strategy and resources, rather than be treated as one variable.

Next, in future iterations of this model, real world data should be utilized to understand the mathematical relationship among the variables as to enhance the results of the model experiments. Another interesting scenario to run within the experiments would be the expansion of state resources. Specifically, states capacity should reflect their ability to call upon their partners and allies to include membership in international organizations. It is through alliances and membership in international organizations that states are able to multiply their resources, construct a coherent strategy, and convert power together when it might not have been able to do so alone. For example, the United States faces a grim reality in the showdown in the Indo-Pacific with China should it face China alone by standard measures of hard power. However, by calling upon allies and partners in the region, namely Japan and Australia, the United States' ability to project power in the Indo-Pacific is arguably more than enough to win a fight against China.

Shock Enhancements

Equally important as the states in this model, and just as diverse, are the shocks in the international environment. The model as it is currently capturing shocks as uniform. That is, they have no distinguishing features from one another other than their intensity value. In future iterations of the model, introducing a variable such as shock type would be of value. Doing so would allow the user to better understand what the impact of a particular type of shock is to the state's propensity variables rather than its antifragility level overall. Making this distinction, can further aid International Relations scholars in understanding "under what conditions" or "under which type of shock" a state is likely to be impacted the most.

Furthermore, the shocks in the model should include their magnitude and duration and further divided into shocks and stressors. Stressors might be characterized by a smaller magnitude and longer duration, whereas a shock is defined by a higher magnitude and shorter duration.

CONCLUSION

In conclusion, the theoretical model of state antifragility presented in this dissertation provides scholars and practitioners in International Relations with a unique understanding of the importance nuances of states and state behavior. Specifically, the use of modeling and simulation paves the way to generate a theory of state antifragility in International Relations. In turn, this theory can be used to supplement current theoretical paradigms explanatory power of state behavior when exploring why some states fair better under stress than others, ceteris parabus.

Second, by identifying the three propensity variables of state antifragility, these measures can be added to the aforementioned indices and monitored to allow International Relations scholars and practitioners to anticipate who the next “winners” and “losers” might be in the next global crisis or conflict. As evidenced by the results of the experiments in Chapter 5, how well a state learns (or how forgetful it is) directly impacts its capacity to be antifragile. Having knowledge of how well a state learns (or forgets) can help us monitor the health and wellbeing of a state and anticipate necessary interventions or aid in the face of an impending crisis.

Third, the application of case studies in Chapter 6 and Chapter 7 provide evidence to suggest that challenges the prevailing assumptions about the violent extremist organizations in the War in Iraq and the first of China in the Indo-Pacific. Specifically, the case study on the United States and Al Qaeda in Iraq (AQI) during the War in Iraq (2003-2011) revealed that violent extremist organizations can possess the same three propensity variables of states and how two of those propensity variables, learning and agility, benefited AQI. A lack of these same two variables, however, hindered the most powerful military in the world against this insurgent force. Overall, this case study questions the notion in Realism that though states are the principal actor in international relations, other bodies exist whose power is limited. In the case of AQI and the United States in the Iraq War (2003-2011), AQI proved to be more powerful than the United States for a certain period of time.

Additionally, the case study of the great power competition between United States and China illuminates the potential weaknesses of China as this great power competition evolves in the Indo-Pacific. In particularly, China’s centralized governance structure and lack of history of surviving past shocks may play a role in China becoming more fragile over time. By traditional measures of power, both military and economic, China outperforms the United States. However, when examined through the lens of antifragility, two key variables provide International Scholars and practitioners with potential weaknesses of China that may render it more fragile than previously considered.

Finally, by expanding upon Arnold Wolfers' 1960s billiard ball model, the agent-based model in this dissertation illuminates the important, symbiotic relationship between state antifragility and stress in a way that is counterintuitive to the original model by Wolfers. That is to say, states need some level of stress or anarchy in the international environment in order to become antifragile or maintain antifragility once it is achieved. How much stress is dependent upon the three propensity variables the state possesses, which influence its capacity to become antifragile. The reimagination of stressors as an opportunity to become antifragile rather than a detriment to states to be avoided has implications for the way states perceive and interact with stressors in the international environment. Furthermore, the addition of antifragility to indices such as the FSI or OECD index has the potential to reconfigure the way we think about the hierarchy of nations our international political order. That is states who see a lot of volatility, yet benefit from that volatility may signal strength, not weakness as currently perceived.

By creating an explicit, theoretical model, others are encouraged to challenge the assumptions and evolve the model to take it from the theoretical to the practical.

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APPENDIX A

OVERVIEW, DESIGN CONCEPTS, AND DETAILS (ODD) PROTOCOL

1. Overview

1.1 Purpose and Patterns

The purpose of this model is to model of state antifragility in order to understand the different levels of state antifragility and fragility make for state performance and survival.

1.2 State Variables and Scales

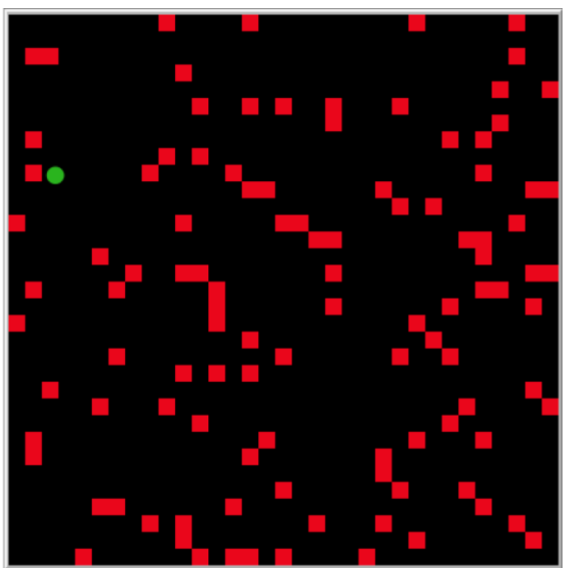
The interaction between a single state and shocks in the international environment is simulated in this model. The environment can be divided into two patch types. The first patch is denoted by the color red and represents a shock. These patches possess an intensity value which is determined by a Gamma distribution. The skewedness and scale of the shock's intensity is determined by two variables, alpha and lambda. The calculation of alpha and lambda come from the user input of the two variables gamma-mean and gamma-variance. Table 1.0 demonstrates the relationship of the gamma-mean and gamma-variance variables to the alpha and lambda variables that determine the skewedness and scale of the Gamma distribution.

The second type of patch is a peaceful patch distinguished by the color black. These patches have no intensity; thus, they do not really interact with the state. Figure 1.0 provides a visualization of the environment in NetLogo.

Table 44: How the Intensity of the Shock is Determined

Variable	Code	Meaning
Gamma-mean	Gamma-mean number-mean	This is a slider variable determined by the user in the Interface Tab whose range is (0,10) with incremental increases at 1.
Gamma-variance	Gamma-variance number-variance	This is a slider variable determined by the user in the Interface Tab whose range is (0,10) with incremental increases at 1.
Alpha	((Gamma Mean *(gamma-mean)/gamma-variance)	NetLogo code for determining the alpha variable.
Lambda	((1) /((gamma-variance)/ (gamma-mean)	NetLogo code for determining the lambda variable.
Intensity	Random-gamma alpha lambda	Use a gamma distribution defined by alpha and lambda to determine the values of the shocks' intensities.

Figure 43: Simulation Environment with 100 Shocks



The primary agents in the model are states. For the purpose of simplification, one agent is used. The agents are endowed with certain characteristics. States have a size, a random location in the environment, and a default shape (Table 1.1). Furthermore, states are endowed with characteristics of fragility/antifragility. These characteristics include capacity, percent-learn, percent-forget, recoverytime, performance, and recoveryperiod.

Table 45: Agent Attributes and Attribute Descriptions

Agent Attribute	**Description**
size	The size of the agent.
setxy	The location of the agent in the environment.
shape	The shape of the agent.
Capacity	The capacity of the agent to become antifragile.
Percent-forget	The capacity of the agent to forget from its previous experiences (expressed as a percent).
Percent-learn	The capacity of the agent to learn from its previous experiences (expressed as a percent).
Recoverytime	The amount of time it takes an agent to recovery from experiencing a shock.
Performance	The ability of the agent to absorb a future shock.

1.2 Process Overview and Scheduling

The model proceeds in time steps (ticks) that have no specific equivalency, but rather allow for relative interactions. With each time-step the state either runs into a black patch in which no interaction occurs, or it runs into a red patch (shock) in which an interaction occurs. As the state moves and does not run into a shock, it's capacity to forget increases as it has not incurred any shocks to potentially learn from.

States begin with a level of performance (*number-performance)* and an antifragility capacity variable (*number-capacity*) which depending upon which thresholds for the variable they cross lead the state to be classified as fragile, antifragile, or resilient. Until a state hits a shock, the state will maintain the same performance value (*number-performance*). However, as the literature on antifragility reviewed above emphasizes, lack of experience with shocks can render a state more fragile. Hence over time (and conditional upon the magnitude of the forgetting parameter) state antifragility capacity may degrade, with initially antifragile states potentially transitioning to resilient states, and ultimately to fragile states if no shocks are encountered for a prolonged period relative to the magnitude of the forgetting parameter, (capacity * (1-percent-forget)).

When a state encounters a shock (h) in a time period (t), several things happen. First its performance is immediately degraded. Performance is reduced by shock magnitude, and if state performance drops below zero ($S_t \leq 0$), the state will die, and the simulation terminates. Then the parameters for the recovery process are set. Recovery magnitude (m) is set, based on state fragility, resilience, or antifragility and number of recovery periods (p). For fragile state the total recovery experienced is less than the hit from the shock (mp < h), for resilient states recovery will eventually return the state to its prior level (mp = h), and for antifragile states recovery will eventually lead to performance above the level initially possessed by the state (mp > h.)

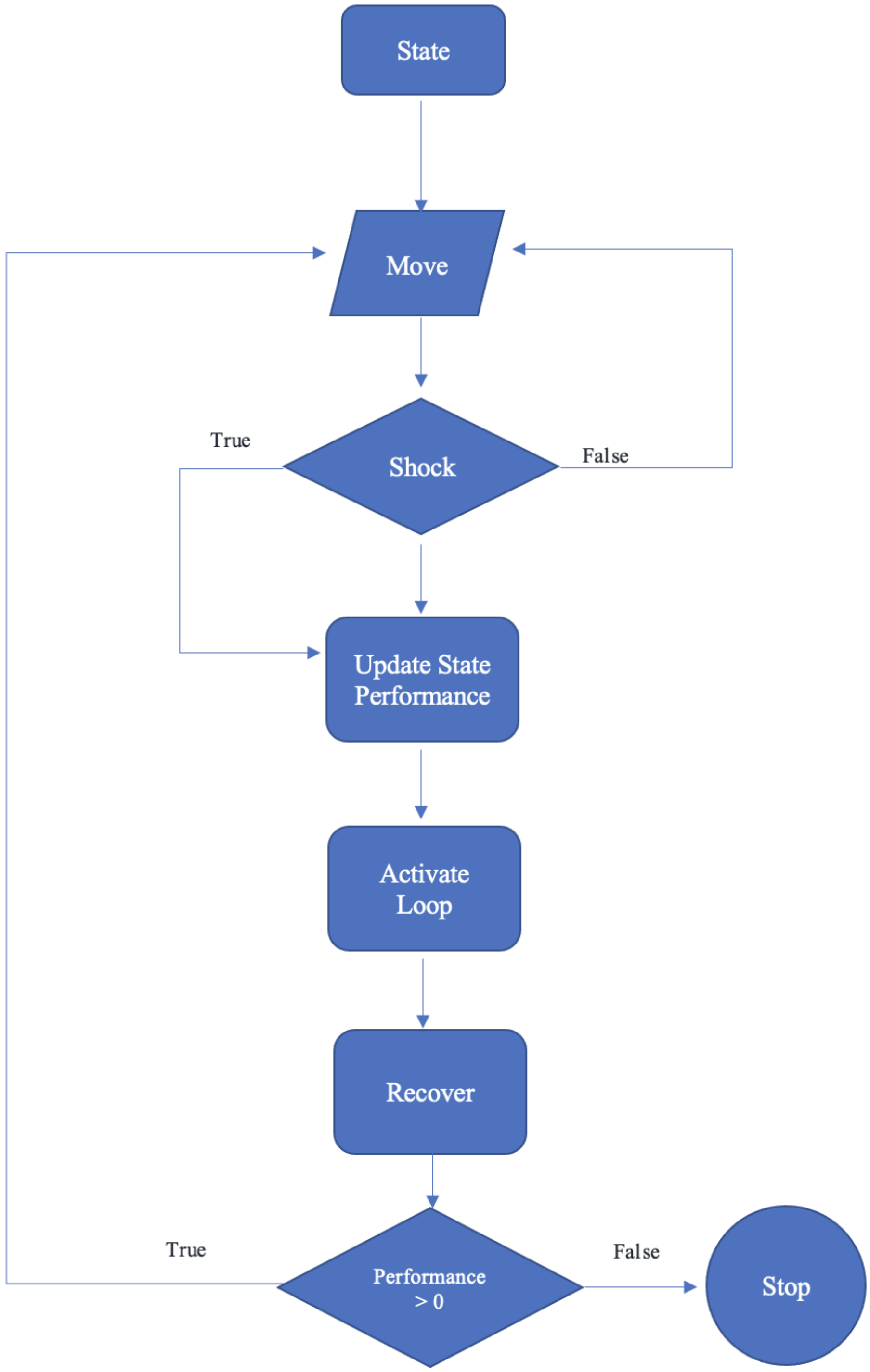
Hitting a shock may also allow a state to develop its antifragility capacity, rendering it better able to deal with future shocks. Thus, the third major event when a state hits a shock involves learning, modeled as an increase in the antifragility capacity variable. Depending upon magnitude of the learning parameter, state antifragility capacity increases, potentially moving a fragile state up to a capacity level that renders it resilient, or a resilient state up to a level of capacity that means it will be antifragile if it encounters another shock before this capacity degrades.

After hitting a shock, the state enters the recovery period. During each turn of the recovery period (p) state performance recovers by the recovery magnitude ($S_{t+1} = S_t + m$). At the conclusion of the recovery period, a fragile state will have recovered to a level of performance below its previous performance, a resilient state will have returned to its initial performance level, and an antifragile state will have recovered to a level of performance better than its initial performance. After the recovery period ends, a state will begin to once again begin to forget antifragility capacity (conditioned by the magnitude of the forgetting parameter) until it once more encounters a shock.

The conclusion of the recovery period is dependent upon the type of state. A fragile state will recover to a level of performance below its previous performance; a resilient state will return to its initial performance level. An antifragile state recovers to a level of performance better than its initial performance.

There are two conditions under which the simulation will terminate. First, if state performance drops below zero, then the state can no longer perform, and it "dies." The death of a state triggers one condition for simulation termination. The second condition is one of time. Captured in Chapter 5, some states will "break away" and continue to be antifragile forever until some imposed condition. As a result, when the simulation reaches 2000 ticks, the other condition for simulation termination is met.

Figure 44: Process Overview Diagram



1.4 Design Concepts

1.4.1 Basic Principles

The first basic principle is that states are the primary actors that are endowed with certain fragile/antifragile characteristics. These characteristics include a performance value, a capacity value, a percent-learning value, a percent-forget value, a recoverytime and a recoveryperiod.

The second basic principle is that stress must be present in the simulation environment and vary depending on how chaotic the environment is. Codified in the model as a shock, stress is defined as anything that disrupts a state's performance and may impact the state's antifragility capacity. There are two important characteristics of stress that must be accounted for in the model. First, how chaotic or stressful the environment is for a state is determined by the number of stressors present in the environment. The fewer number of shocks in the environment, the less chaotic the environment can be perceived to be. The greater the number of shocks in the environment, the more chaotic the environment can be perceived to be. The second important characteristic of stress is the intensity of those stressors or shocks. The intensity of a stressor is indicative of the severity of the stress, given that stressors may vary from small scale to large scale.

The third basic principle is that states interact with stress in the environment and stress has some effect on the state. Subsequently, what is most important about this interaction is the effect the stress has on states. Second, the frequency with which states experience stress is critical to the stress' effect on the state. One intense stressor may have the same effect on a state as a clustered series of less intense stressors, particularly as it pertains to a state's recovery efforts.

The final basic principle is the categorization of the three state types that occurs as a result of the stress-state interaction. The three state types are fragile, resilient, and antifragile. In the model, each is determined by the state's capacity variable, which is in turn related to how well the state recovers after experiencing stress. If a state's capacity is too small, then after experiencing stress, the state's ability to perform is reduced immediately and recovery during the state's recovery period is too small to recover. This type of state is considered fragile. Antifragile states are discerned by their high capacity, such that after experiencing stress, the state's ability to perform is reduced immediately, but during the recovery period the state recovers to a level better than the original level known prior to experiencing the stress. Finally, the resilient state is one who's capacity falls somewhere in-between the fragile and antifragile state. It's ability to perform is reduced immediately after experiencing a shock, too; however, the resilient state recovers to a level previously known prior experiencing the same shock.

1.4.2 Interaction

Interaction occurs between the state and the shock. When a state encounters a shock (h) in a time period (t), several things happen. First its performance is reduced by shock magnitude ($S_t = S_{t-1} - h$), and if state performance drops below zero ($S_t \leq 0$), the state will die, and the simulation terminates. Next the parameters for the recovery process are set. Recovery magnitude (m) is set, based on state fragility, resilience or antifragility and number of recovery periods (p). For fragile state the total recovery experienced is less than the hit from the shock ($mp < h$), for resilient states recovery will eventually return the state to its prior level ($mp = h$), and for antifragile states recovery will eventually lead to performance above the level initially possessed by the state ($mp > h$).

Hitting a shock may also allow a state to develop its antifragility capacity, rendering it better able to deal with future shocks. Thus, the third major event when a state hits a shock involves learning, modeled as an increase in the antifragility capacity variable. Depending upon magnitude of the learning parameter, state antifragility capacity increases, potentially moving a fragile state up to a capacity level that renders it resilient, or a resilient state up to a level of capacity that means it will be antifragile if it encounters another shock before this capacity degrades.

After hitting a shock, the state enters the recovery period. During each turn of the recovery period (p) state performance recovers by the recovery magnitude ($S_{t+1} = S_t + m$). At the conclusion of the recovery period, a fragile state will have recovered to a level of performance below its previous performance, a resilient state will have returned to its initial performance level, and an antifragile state will have recovered to a level of performance better than its initial performance. After the recovery period ends, a state will begin to once again begin to forget antifragility capacity (conditioned by the magnitude of the forgetting parameter) until it once more encounters a shock.

1.4.3. Learning

How the state changes its traits over time is a consequence its experience(s) with the shock(s). In addition to recovery and antifragility capacity, it is also about learning and forgetting. The state's ability to learn is derived from its previous experiences and impacts its antifragile capacity. For example, the intensity of the shock is multiplied by the percent-learn value of the state. This value is then added to the capacity value of the state to determine the updated capacity value.

1.4.4. Stochasticity

The interaction between the state and the shocks is a stochastic process because the state moves about the world randomly. That is, the state is not seeking to avoid nor to encounter shocks.

Additionally, the intensity of the shocks is determined by pulling a random gamma variable based on a user defined gamma mean and gamma variance (Table 1.0). While the number of shocks in the environment is predetermined, how intense those shocks are is based on the alpha and lambda parameters, each of which is defined by the gamma mean and gamma variance parameters and summarized below.

- Alpha = ((gamma mean *gamma mean)/ (gamma variance)
- Lambda= (1/ gamma variance/ gamma mean)

1.4.5. Observation

Information is collected in the simulation via NetLogo's "to report" command and plot features. In the model, the performance of the state, capacity, total number of shocks, fragile length (number of tics spent with a fragile capacity level), resilient length (number of tics spent with a resilient capacity level), antifragile length, life length, and whether or not the state survived are all captured via the "to report" command. Additionally, the state's performance and capacity are monitored and plotted on a graph, along with the type of state the agent is.

1.5 Details

1.5.1 Initialization

The initialization of the model is based on the number of shocks in the environment. There are a total of three stages during the initialization process: (1) create shocks, (2) create states, (3) the ticks are reset to zero. Tables 1.2 and 1.3 list the variables and their range of initial values.

Table 46: Initialization Parameters Default Values for Shocks

Environment Variables	Parameters
Gamma Mean	(0, 10) and increases in increments of 1
Gamma Variance	(0, 10) and increases in increments of 1
Number of Shocks	(0, 400) and increases in increments of 1

For the state, initialization variables include capacity, performance, percent-learn, percent-forget, recovery period, and recovery time. Table 1.3 summarizes the initialization parameters' default values for the agent.

Table 47: Initialization Parameters Default Values for the State

Agent Variables	Parameters
Capacity	(0, 15) changes in increments of 1
Performance	(0, 40) changes increments of 1
Percent-Learn	(0, 1) changes in increments of 0.01
Percent-Forget	(0, 1) changes in increments of 0.01
Recovery Period	0
Recovery Time	(0, 20), changes in increments of 1

1.5.2 Input Data

The model does not use input data to represent time-varying processes.

APPENDIX B

FINAL MODEL CODE

```
globals [
  number-dead
  gamma-mean
  gamma-variance
  alpha
  lambda
]

breed [states state]

states-own [ ;; States own 14 attributes attributes.
  capacity ;; The agent's capacity variable plays a role in both the recoveryperiod variable and helps determine the categories for the different state types, which in turn determines how a state recovers.
  performance ;; The agent's performance variable
  percent-learn ;; The percent-learn variable determines how well the state learns.
  percent-forget ;; The percent-forget variable determines how the state forgets.
  category ;; Category designates what type of state the agent is throughout the simulation.  That is it may be fragile, resilient, or antifragile.
  recoveryperiod ;; The recoveryperiod
  recoverymagnitude ;; The recoverymagnitude variable determines the size with which the agent recovers- decrease by 10% (fragile agent), 0% (resilient agent), or increase by 10% (antifragile agent).
  recoverytime ;; The recoverytime varaible determines how long it takes the agent to recover after interacting with a shock.
  fragile-length ;; This variable records how many ticks the agent spent being fragile.
  resilient-length ;; This variable records how many ticks the agent spent being resilient.
  antifragile-length ;; This variable records how many ticks the agent spent being antifragile.
  life-length ;; this variable records how long the agent's life was throughout the simulation (in ticks).
  countshock ;; This variable records the number of shocks the agent encounters thoughout the simulation.
  survived-to-end? ;; Did the agent survive to the end of the simulation? The variable 1 is stored for yes, and the variable 0 is stored for no.
]

patches-own [intensity]
```

;; TO SET UP ;;

to setup ;; To set up the simulation, clear the world, grow the shocks/stressors, grow the states, initalize the plots and reset ticks.
  clear-all
  grow-shocks
  grow-states
  setup-plots
reset-ticks
end

;; TO GROW SHOCKS ;;

to grow-shocks ;; To grow shocks in the environment, set up number of shocks, make their color red, and set their intensity.
  ask n-of number-shocks patches [;; This is a slider variable that controls the inital number of shocks whose range spans (0,100).
    set pcolor red ;; Shocks are represented by red patches.
    set gamma-mean number-mean ;; This is a slider variable set in the Interface Tab whose range is is (0,10).
    set gamma-variance number-variance ;; This is a slider variable set in the Interface Tab whose range is (0,10).
    set alpha ((gamma-mean)*(gamma-mean)/(gamma-variance)) ;; This is the calulation for the alpha variable in the Gamma distribution.
    set lambda ((1) / ((gamma-variance)/(gamma-mean))) ;; This is the calclation for lambda variable in the Gamma distribution.
    set intensity random-gamma alpha lambda ;; Using the input from the for gamma-mean variable and gamma-variance variable from a Gamma distribution, set the intensity of the shocks.
  ]
end

;;TO GROW STATES;;

to grow-states ;; To grow states in the environment, set the agent's shape, randomly disperse it throughout the environment, set it's intial capacity, percent-learn, percent-forget,recoverytime, and performance values. Also set the recoveryperiod to 0 and set the state type.
  set-default-shape states "dot" ;; Set the shape of states to dot.
  create-states 1 [;; Create 1 state.
    setxy random-xcor random-ycor ;; Randomly disperse them throughout the environment.
    set size 2.5 ;; Set the size of the dot to 2.5.
    set capacity number-capacity ;; Set the capacity variable of the agent using the slider variable number-capacity in the Interface tab.

```
    set percent-learn percentnumber-learn ;; Set the percent-learn variable of the state using the
slider variable percentnumber-learn in the Interface tab.
    set percent-forget percentnumber-forget ;; Set the percent-forget variable of the agent using
the slider variale percentnumber-forget in the Interface tab.
    set recoverytime recoverynumber-time ;; Set the recoverytime of the agent using the slider
variable recoverynumber-time in the Interface tab.
    set performance number-performance  ;; Set the inital performance varaible by using the slider
variable number-performance in the Interface tab.
    set recoveryperiod  0 ;; Set the state's inital recoveryperiod to 0.
    update-state-type ;; This procedure determines the type of state (fragile, resilient, or
antifragile) based on the capacity variable value.
    set countshock  0 ;; Set the countshock monitor to 0.
  ]
end
```

;; TO GO ;;

```
to go ;; To go, ask states to move about the environment, interact with a shock if it comes across
it, update plots in the model, and die.
  ask states [
    move-states ;; This calls the move-states procedure.
    interact-with-shocks ;; This calls the interact-with-shocks procedure.
    update-plots ;; This updates the model plots.
    death ;; This calls the death procedure.
  ]
  tick ;; This advances the time clock by one tick.
;;  if ticks >= 1000 [ stop ]
  if ([performance] of state 0 <= 0 ) [ask state 0 [death] stop] ;; This condition is set at the onset
of the simulation. The condition states if the performance of the state is less than or equal to zero,
then the state should die and simulation stop.
end
```

;; TO MOVE ;;

```
to move-states ;; To move, ask states to move about the world randomly and bounce off the
walls.
  right random 15
  left random 15
  forward 1 ;; The previous three lines give the state a random movement throughout the world.
  if abs pxcor = max-pxcor ;; The following four lines of code ask the state to bounce of the
walls.
    [ set heading (- heading) ]
  if abs pycor = max-pxcor
    [ set heading (180 - heading) ]
```

if recoveryperiod <= 0 ;; If the recoverperiod of the state is less than or equal to 0, it is no longer recoverying and the agent's capacity will begin to forget. The recoverymagnitude also becomes 0.
[set capacity (capacity * (1 - percent-forget))
set recoveryperiod (0)
set recoverymagnitude (0)]
if recoveryperiod > 0 [recover] ;; If the recoveryperiod is greater than 0, the agent should recover by calling the recover procedure. In addition, the state should update it's state type.
update-state-type
set life-length ticks ;; Calculate the length of the agent.
end

;; TO INTERACT ;;

to interact-with-shocks ;; To interact with shocks update the state's performance, activate loop, and count the number of shocks encountered.
if pcolor = red [;; If the state encounters a shock (red patch), then call the update-state-performance and activate-loop procedures. Also count the shock.
update-state-performance
activate-loop
countshocks
]
end

;; TO UPDATE STATE PERFORMANCE;;

to update-state-performance;; Overall, to update the state's performance, the recoverymagnitude must be updated. How the recoverymagnitude is calculated is determined by the intensity of the shock, the recoverytime, the recoverymagnitude and recoveryperiod of the agent at the time it hits the shock.
ifelse capacity > 10 ;; If the capacity of the state is greater than 10, let the recoverymagnitude increase by 10%.
[set recoverymagnitude (((intensity * 1.2) / recoverytime) + (recoverymagnitude * recoveryperiod / recoverytime))]
[ifelse capacity < 4 ;; If the capacity of the state is less than 3, let the recoverymagnitude decrease by 10%. If the capacity of the state is between 3 and 10, let the recoverymagnitude neither increase nor decrease.
[set recoverymagnitude (((intensity * 0.8)/ recoverytime) + ((recoverymagnitude * recoveryperiod) / recoverytime))]
[set recoverymagnitude (((intensity) / recoverytime) + (recoverymagnitude * recoveryperiod / recoverytime))]]

set performance (performance - intensity) ;; Set the state's performance to performance - intensity, meaning all states initially take a hit from the shock.

```
  set recoveryperiod recoverytime ;; Update the recoveryperiod to equal that of the recoverytime value.
end
```

;; TO ACTIVATE LOOP;;

```
to activate-loop ;; To activate the loop the state's performance value must be greater than 0, then the state's capcacity is updated based on the equation (capacity + percent-learn value * intensity of the shock).
  if performance > 0
     [set capacity (capacity + (percent-learn * intensity))]
end
```

;;TO COUNTSHOCK;;

```
to countshocks ;; Advances the countshock function.
  set countshock (countshock + 1)
end
```

;; TO RECOVER;;

```
to recover ;; For the agent to recover, set the agent's performance to the agent's performance + the recoverymagnitude
  set performance (performance + recoverymagnitude)
  set recoveryperiod (recoveryperiod - 1)
end
```

;; TO UPDATE STATE TYPE;;

```
to update-state-type ;; The agent's type (fragile, resilient, or antifragile) is determined by the capacity value.
  if capacity > 10 ;; If the state's capacity is greater than 10, set the agent's color green and consider it antifragile. Track the amount of time the agent has spent being antifragile.
     [set color green set category "anti-fragile"
     set antifragile-length antifragile-length + 1]
  if capacity <= 10 and capacity >= 4 ;; If the state's capacity value is less than or equal to 10 and greater than or equal to 3, turn the agent's color yellow and consider it resilient. Track the amount of time the agent has spent being resilient.
     [set color yellow set category "resilient"
     set resilient-length resilent-length + 1]
  if capacity < 4 ;; If the state's capacity value is less than 3, turn the agent's color red and consider it fragile. Track the amount of time the agent has spent being fragile.
```

```
    [set color red set category "fragile"
    set fragile-length fragile-length + 1]
end
```

;;TO DIE;;

```
to death ;; If the state has a performance value less than or equal to 0, then it cannot function and must die.
  if performance <= 0 [ set performance -1 ]  ;; set life-length ticks ;; record how many ticks the agent survived
  ifelse ticks <= 1000  ;; Change for the age of state max
  [set survived-to-end? 0]
  [set survived-to-end? 1]
  set life-length ticks
;;  stop

end
```

;; TO REPORT CAPACITY;;

```
to-report state-capacity
  report[ capacity ] of state 0
end
```

;; TO REPORT PERFORMANCE;;

```
to-report state-performance
  report [performance] of state 0
end
```

;;TO REPORT NUMBER OF SHOCKS HIT;;

```
to-report number-of-shocks-hit
  report [countshock] of state
```

APPENDIX C

AMERICAN INVOLVEMENT IN ARMED CONFLICT SINCE WORLD WAR I- 2000 [248]

Dates	Descriptions
1914-1918	**World War I.** On April 16, 1917, the United States declared war with Germany and on December 7, 1917, with Austria-Hungary. Entrance of the United States into the war was precipitated by Germany's submarine warfare against neutral shipping.
1917-1922	**Cuba.** U.S. forces protected American interests during an insurrection and subsequent unsettled conditions. Most of the United States Armed Forces left Cuba by 1919, but two companies remained at Camaguey until February 1922.
1918-1919	**Mexico.** After withdrawal of the Pershing expedition, U.S. troops entered Mexico in pursuit of bandits at least three times in 1918 and six times in 1919. In August 1918 American and Mexican troops fought at Nogales.
1918-1920	**Panama.** U.S. forces were used for policy duty according to treaty stipulations, in Chiriquí Province, during election disturbances and subsequent unrest. **Soviet Russia.** Marines were landed at and near Vladivostok in June and July to protect the American consulate and other points in the fighting between the Bolshevik trips and the Czech Army, which had traversed Siberia from the western front. A joint proclamation of emergency government and neutrality was issued by the American, Japanese, British, French, and Czech commanders in July. In August 7,000 men were landed in Vladivostok and remained until January 1920, as part of an allied occupation force. In September 1918, 5,000 American troops joined the allied intervention force and Archangel and remained until June 1919. These operations were in response to the Bolshevik revolution in Russia and were partly supported by Czarist or Kerensky elements.
1919	**Dalmatia.** U.S. forces were landed at Trau (now Trogir, Croatia) at the request of Italian authorities to police order between the Italians and Serbs. **Turkey.** Marines from the USS Arizona were landed to guard the U.S. Consulate during the Greek occupation of Constantinople. **Honduras.** September 8 to 12. A landing force was sent ashore to maintain order in a neutral zone during an attempted revolution.
1920	**China.** March 14. A landing force was sent ashore for a few hours to protect lives during a disturbance at Kiukiang (Jiujiang). **Guatemala.** April 9 to 27. U.S. forces protected the American legion and other American interests, such as the cable station, during a period of fighting between Unionists and the government of Guatemala.
1920-1922	**Russia (Serbia).** February 16, 1920, to November 19, 1922. A Marine guard was sent to protect the United States radio station and property on Russian Island, Bay of Vladivostok.

[248] Congressional Research Service, Instances of Use of United States Armed Forces Abroad, 1789-2020, Updated July 20, 2020, Retrieved From: https://fas.org/sgp/crs/natsec/R42738.pdf

1921	**Panama-Costa Rica.** American naval squadrons demonstrated in April on both sides of the Isthmus to prevent war between the two countries over a boundary dispute.
1922	**Turkey.** September and October. A landing force was sent ashore with consent of both Greek and Turkish authorities to protect American lives and property when the Turkish Nationalists entered Smyrna.
1922-1923	**China.** Between April 1922 and November 1923 marines were landed five times to protect Americans during periods of unrest.
1924	**Honduras.** February 28 to March 31, September 10 to 15. U.S. forces protected American lies and interest during election hostilities. **China.** September. Marines were landed to protect Americans and other foreigners in Shanghai during Chinese factional hostilities.
1925	**China.** January 15 to August 29. Fighting of Chinese factions accompanied by riots and demonstrations in Shanghai brought the landing of American forces to protect lives and property in the International Settlement. **Honduras.** April 19 to 21. U.S. forces protected foreigners at La Ceiba during a political upheaval. **Panama.** October 12 to 23. Strikes and rent riots led to the landing of about 600 American troops to keep order and protect American interests.
1926-1933	**Nicaragua.** May 7 to June 5, 1926; August 27, 1926, to January 3, 1993. The coup d'état of General Chamorro aroused revolutionary activities leading to the landing of American marines to protect the interests of the United States. United States forces came and went intermittently until January 3, 1933.
1926	**China.** August and September. The Nationalist attack on Hankow brought the landing of American naval forces to protect American citizens. A small guard was maintained at the consulate general even after September 16, when the rest of the forces were withdrawn. Likewise, when Nationalist forces captured Kiukiang, naval forces were landed for the protection of foreigners November 4 to 6.
1927	**China.** February. Fighting at Shanghai caused American naval forces and marines to be increased. In March a naval guard was stationed at the American consulate at Nanking after Nationalist forces captured the city. American and British destroyers later used shell fire to protect Americans and other foreigners. Subsequently additional forces of marines and naval vessels were stationed in the vicinity of Shanghai and Tientsin.
1932	**China.** American forces were landed to protect American interest during the Japanese occupation of Shanghai.
1933	**Cuba.** During a revolution against President Gerardo Machado naval forces demonstrated but no landing was made.
1934	**China.** Marines landed at Foochow to protect the American Consulate.
1940	**Newfoundland, Bermuda, St. Lucia, Bahamas, Jamaica, Antigua, Trinidad, and British Guiana.** Troops were sent to guard air and naval bases obtained by negotiation with Great Britain. These were sometimes called lend-lease bases.
1941	**Greenland.** Greenland was taken under protection of the United States in April. **Netherlands (Dutch Guiana).** In November the President ordered American troops to occupy Dutch Guiana, but by agreement with the Netherlands

	government in exile, Brazil cooperated to protect aluminum ore supply from the bauxite mines in Suriname. **Iceland.** Iceland was taken under the protection of the United States, with consent of its government, for strategic reasons. **Germany.** Sometime in the spring the President ordered the Navy to patrol ship lanes to Europe. By July U.S. warships were convoying and by September were attacking German submarines. In November, the Neutrality Act was partly repealed to protect U.S. military aid to Britain.
1941-1935	**World War II.** On December 8, 1941, the United States declared war with Japan, on December 11 with Germany and Italy, and on June 5, 1942, with Bulgaria, Hungary, and Romania. The United States declared war against Japan after the surprise bombing of Pearl Harbor, and against Germany and Italy after those nations, under the dictators Hitler and Mussolini, declared war against the United States. The United States declared war against Bulgaria, Hungary, and Romania in response to the declarations of war by those nations against the United States.
1945	**China.** In October 50,000 U.S. Marines were sent to North China to assist Chinese Nationalist authorities in disarming and repatriating the Japanese in China and in controlling ports, railroads, and airfields. This was in addition to approximately 60,000 U.S. forces remaining in China at the end of World War II.
1946	**Trieste.** President Truman ordered the augmentation of U.S. troops along the zonal occupation line and the reinforcement of air forces in northern Italy after Yugoslav forces shot down an unarmed U.S. Army transport plane flying over Friuli Venezila Giulia. Earlier U.S. naval units had been dispatched to the scene.
1948	**Palestine.** A marine consular guard was sent to Jerusalem to protect the U.S. Consul General. **Berlin.** After the Soviet Union established a land blockade of the U.S., British, and French sectors of Berlin on June 24, 1948, the United States and its allies airlifted supplies to Berlin until after the blockade was lifted May 1949.
1948-1949	**China.** Marines were dispatched to Nanking to protect the American embassy when the city fell to Communist troops, and to Shanghai to aid in the protection and evacuation of Americans.
1950-1953	**Korea War.** The United States responded to North Korean invasion of South Korea by going to its assistance, pursuant to United Nations Security Council resolutions. U.S. forces deployed in Korea exceeded 300,000 during the last year of the conflict. Over 36,6000 U.S. military were killed in action.
1950-1955	**Formosa (Taiwan).** In June 1950 at the beginning of the Korean War, President Truman ordered the U.S. Seventh Fleet to prevent Chinese Communist attacks upon Formosa and Chinese Nationalist operations against mainland China.
1954-1955	**China.** Naval units evacuated U.S. civilians and military personnel from the Taschen (Dachen) Islands.
1956	**Egypt.** A maritime battalion evacuated U.S. nationals and other persons from Alexandria during the Suez crisis.
1958	**Lebanon**. Marines were landed in Lebanon at the invitation of its government to help protect against threatened insurrection supported from the outside. The

	President's action was supported by a congressional resolution passed in 1957 that authorized such actions in that area of the world.
1959-1960	**The Caribbean.** 2d Marine Ground Task Force was deployed to protect U.S. nationals during the Cuban Crisis.
1962	**Thailand.** The 3d Marine Expeditionary Unit landed on May 17, 1962, to support that country during the threat of Communist pressure from outside; by July 30 the 5,000 marines had been withdrawn. **Cuba.** On October 22, President Kennedy instituted "quarantine" on the shipment of offensive missiles to Cuba from the Soviet Union. He also warned the Soviet Union that the launching of any missile from Cuba against any nation in the Western hemisphere would bring about U.S. nuclear retaliation on the Soviet Union. A negotiated settlement was achieved in a few days.
1962-1975	**Laos.** From October 1962 until 1975, the United States played an important role in military support of anti-Communist forces in Laos.
1964	**Congo.** The United States sent four transport planes to provide airlift for Congolese troops during a rebellion and to transport Belgian paratroopers to rescue foreigners.
1964-1973	**Vietnam War.** U.S. military advisers had been in South Vietnam for a decade, and their numbers had been increased as the military position of the Saigon government became weaker. After citing what her termed were attacks on U.S. destroyers in the Tonkin Gulf, President Johnson asked in August 1964 for a resolution expressing U.S. determination to support freedom and protect peace in Southeast Asia. Congress responded with the Tonkin Gulf Resolution, expressing support for "all necessary measures" the President might take to repel armed attack against U.S. forces and prevent further aggression. Following this resolution and following a Communist attack on a U.S. installation in central Vietnam, the United States escalated its participation in the war to a peak of 5430,000 military personnel by April 1969.
1965	**Dominican Republic.** The United States intervened to protect lives and property during a Dominican revolt and sent more troops as fears grew that the revolutionary forces were coming increasingly under Communist control.
1967	**Congo.** The United States sent three military transport aircraft with crews to provide the Congo central government with logistical support during a revolt.
1970	**Cambodia.** U.S. troops were ordered into Cambodia to clean out Communist sanctuaries from which Viet Cong and North Vietnamese attacked U.S. and South Vietnamese forces in Vietnam. The object of this attack, which lasted from April 30 to June 30 was to ensure the continuing safe withdrawal of American forces from South Vietnam and to assist the program of Vietnamization.
1974	**Evacuation from Cyprus.** United States naval forces evacuated U.S. civilians during hostilities between Turkish and Greek Cypriot forces.
1975	**Evacuation from Vietnam.** On April 3, 1975, President Ford reported U.S. naval vessels, helicopters, and marines had been sent to assist in evacuation of refugees and U.S. nationals from Vietnam. **Evacuation from Cambodia**. On April 12, 1975, President Ford reported that he had ordered U.S. military forces to proceed with the planned evacuation of U.S. citizens from Cambodia.

	South Vietnam. On April 30, 1975, President Ford reported that a force of 70 evacuation helicopters and 865 marines had evacuated about 1,400 U.S. citizens and 5,500 third country nationals and South Vietnamese from landing zones near the U.S. embassy in Saigon and the Tan Son Nhut Airfield. **Mayaguez incident.** On May 15, 1975, President Ford reported he had ordered military forces to retake the SS Mayaguez, a merchant vessel en route from Hong Kong to Thailand with a U.S. citizen crew which was seized by Cambodian naval patrol boats in international waters and forced to proceed to a nearby island.
1976	**Lebanon.** On July 22 and 23, 1974, helicopters from five U.S. naval vessels evacuated approximately 250 Americans and Europeans from Lebanon during fighting between Lebanese factions after an overland convoy evacuation had been blocked by hostilities. **Korea.** Additional forces were sent to Korea after two American soldiers were killed by North Korean soldiers in the demilitarized zone between North and South Korea while cutting down a tree.
1978	**Zaire.** From May 19 through June 1978, the United States utilized military transport aircraft to provide logistical support to Belgian and French rescue operations in Zaire.
1980	**Iran.** On April 26, 1980, President Carter reported the use of six U.S. transport planes and eight helicopters in an unsuccessful attempt to rescue American hostages being held in Iran.
1981	**El Salvador.** After a guerilla offensive against the government of El Salvador, additional U.S. military advisors were sent to El Salvador, bringing the total to approximately 55, to assist in training government forces in counterinsurgency. **Libya.** On August 19, 1981, U.S. planes based on the carrier USS Nimitz shot down two Libyan jets over the Gulf of Sidra after one of the Libyan jets had fired a heat-seeking missile. The United States periodically held freedom of navigation exercises in the Gulf of Sidra, claimed by Libya as territorial waters but considered international waters by the United States.
1982	**Sinai.** On March 19, 1982, President Regan reported the deployment of military personnel and equipment to participate in the Multinational Force and Observers in the Sinai. Participation had been authorized by the Multinational Force and Observers Resolution, P.L. 97-132. **Lebanon.** On August 21, 1982, President Regan dispatched 800 marines to serve in the multinational force to assist in the withdrawal of members of the Palestine Liberation force from Beirut. The Marines left September 20, 1982.
1982-1983	**Lebanon.** On September 29, 1982, President Regan reported the deployment of 1,200 marines to serve in a temporary multinational force to facilitate the restoration of Lebanese government sovereignty. On September 29, 1983, Congress passed the Multinational Force in Lebanon Resolution (P.L. 98-119) authorizing the continued participation for 18 months.
1983	**Egypt.** After a Libyan plane bombed a city in Sudan on March 18, 11983, and Sudan and Egypt appealed for assistance, the United States dispatched an AWACS electronic surveillance plane to Egypt.
1983-1989	**Honduras.** In July 1983 the United States undertook a series of exercises in Honduras that some believed might lead to conflict with Nicaragua. On March

	25, 1986, unarmed U.S. military helicopters and crewmen ferried Honduran troops to the Nicaraguan border to repel Nicaraguan troops.
1983	**Chad.** On August 8, 1983, President Regan reported the deployment of two AWACS electronic surveillance planes and eight F-15 fighter planes and ground logistical support forces to assist Chad against Libyan and rebel forces. **Grenada**. On October 25, 1983, President Regan reported a landing on Grenada by Marines and Army airborne troops to protect lives and assist in the restoration of law and order and the request of five members of the Organization of Eastern Caribbean States.
1984	**Persian Gulf.** On June 5, 1984, Saudi Arabian jet fighter planes, aided by intelligence from a U.S. AWACS electronic surveillance aircraft and fueled by a U.S. KC-10 tanker, shot down two Iranian fighter planes over an area of the Persian Gulf proclaimed as a protected zone for shipping.
1985	**Italy.** On October 10, 1985, U.S. Navy pilots intercepted an Egyptian airliner and forced it to land in Sicily. The airliner was carrying the hijackers of the Italian cruise ship Achille Lauro, who had killed an American citizen during the hijacking.
1986	**Libya.** On March 26, 1986, President Regan reported to Congress that, on March 24 and 25, U.S. forces, while engaged in freedom of navigation exercises around the Gulf of Sidra, had been attacked by Libyan missiles and the United States had responded with missiles. **Libya.** On April 16, 1986, President Regan reported that U.S. air and naval forces had conducted bombing strikes on terrorist facilities and military installations in Libya. **Bolivia.** U.S. Army personnel and aircraft assisted Bolivia in anti-drug operations.
1987-1988	**Persian Gulf.** After the Iran-Iraq War resulted in several military incidents in the Persian Gulf, the United States increased U.S. joint military forces operations in the Persian Gulf and adopted a policy of reflagging and escorting Kuwaiti oil tankers through the Gulf. President Regan reported that U.S. Navy ships had been fired upon or struck mines or taken other military action on September 23, October 10, and October 20, 1987, and April 19, July 4, 1988. The United States gradually reduced its forces after a cease-fire between Iran and Iraq on August 20, 1988.
1988	**Panama.** In mid-March and April 1988, during a period of instability in Panama and as pressure grew for Panamanian military Leader Manuel Noriega to resign, the United States sent 1,000 troops to Panama, to "further safeguard the canal, U.S. lives, property and interests in the area." The forces supplemented 10,000 U.S. military personnel already in Panama.
1989	**Libya.** On January 4, 1989, two U.S. NavyF-14 aircraft based on the USS John F. Kennedy shot down two Libyan jet fighters over the Mediterranean Sea about 70 miles north of Libya. The U.S. pilots said the Libyan planes had demonstrated hostile intentions. **Panama.** On May 11, 1989, in response to General Noriega's disregard of the results of the Panamanian election, President Bush ordered a brigade-sized force

	of approximately 1,900 troops to augment the estimated 11,000 U.S. forces already in the area. **Andean Initiative in War on Drugs**. On September 15, 1989, President Bush announced that military and law enforcement assistance would be sent to help the Andean nations of Colombia, Bolivia, and Peru combat illicit drug producers and traffickers. By mid-September there were 50-100 U.S. military advisers in Colombia in connection with transport and training in the use of military equipment, plus seven Special Forces teams of 2-12 persons to train troops in the three countries. **Philippines.** On December 2, 1989, President Bush reported that on December 1U.S. fighter planes from Clark Air Base in the Philippines had assisted the Aquino government to repel a coup attempt. In addition, 100 marines were sent from the U.S. Navy base at Subic Bay to protect the U.S. embassy in Manila.
1989-1990	**Panama.** On December 21, 1989, President Bush reported that he had ordered U.S. military forces to Panama to protect the lives of American citizens and bring General Noriega to justice. By February 13, 1990, all the invasion forces had been withdrawn.
1990	**Liberia.** On August 6, 1990, President Bush reported that a reinforced rifle company had been sent to provide additional security to the U.S. embassy in Monrovia, and that helicopter teams had evacuated U.S. citizens from Liberia. **Saudi Arabia.** On August 9, 1990, President Bush reported that he had ordered the forward deployment of substantial elements of the U.S. Armed Forces into the Persian Gulf region to help defend Saudi Arabia after the August 2 invasion of Kuwait by Iraq. On November 16, 1990, he reported the continued buildup of the forces to ensure an adequate offensive military option.
1991	**Iraq.** On January 18, 1991, President Bush reported that he had directed U.S. Armed Forces to commence combat operations on January 16 against Iraqi forces and military targets in Iraq and Kuwait, in conjunction with a coalition of allies and U.N. Security Council resolutions. On January 12 Congress had passed the Authorization for Use of Military Force against Iraq Resolution (P.L. 102-1). Combat operations were suspended on February 28, 1991 **Iraq.** On May 17, 1991, President Bush stated in a status report to Congress that the Iraqi repression of the Kurdish people had necessitated a limited introduction of U.S. forces into northern Iraq for emergency relief purposes. **Zaire.** On September 25-27, 1991, after widespread looting and rioting broke out in Kinshasa, U.S. Air Force C-141s transported 100 Belgian troops and equipment into Kinshasa. U.S. planes also carried 300 French troops into the Central African Republic and hauled back American citizens and third country nationals from locations outside Zaire.
1992	**Sierra Leone.** On May 3, 1992, U.S. military planes evacuated Americans from Sierra Leone, where military leaders had overthrown the government. **Kuwait.** On August 3, 1992, the United States began a series of military exercises in Kuwait, following Iraqi refusal to recognize a new border drawn up by the United Nations and refusal to cooperate with U.N. inspection teams. **Iraq.** On September 16, 1992, President Bush stated in a status report to Congress that he had ordered U.S. participation in the enforcement of a

	prohibition against Iraqi flights in a specified zone in southern Iraq, and aerial reconnaissance to monitor Iraqi compliance with the cease-fire resolution. **Somalia.** On December 10, 1992, President Bush reported that he had deployed U.S. Armed Forces to Somalia in response to a humanitarian crisis and a U.N. Security Council Resolution determining that the situation constituted a threat to international peace. This operation, called Operation Restore Hope, was part of a U.S.-led United Nations Unified Task Force (UNITAF) and came to an end on May 4, 1993. U.S. forces continued to participate in the successor United Nations Operation in Somalia (UNOSOM II), which the U.N. Security Council authorized to assist Somalia in political reconciliation and restoration of peace.
1993	**Iraq.** On January 19, 1993, President Bush said in a status report that on December 27, 1992, U.S. aircraft had shot down an Iraqi aircraft in the prohibited zone; on January 13 aircraft from the United States and coalition partners had attacked missile bases in southern Iraq; and further military actions had occurred on January 17 and 18. Administration officials said the United States was deploying a battalion task force to Kuwait to underline the continuing U.S. commitment to Kuwaiti independence. **Iraq.** On January 21, 1993, shortly after his inauguration, President Clinton said the United States would continue the Bush policy on Iraq, and U.S. aircraft fired at targets in Iraq after pilots sensed Iraqi radar or anti-aircraft fire directed at them. **Bosnia.** On February 28, 1993, the United States began an airdrop of relief supplies aimed at Muslims surrounded by Serbian forces in Bosnia. **Bosnia.** On April 13, 1993, President Clinton reported U.S. forces were participating in a North Atlantic Treaty Organization (NATO) air action to enforce a U.N. ban on all unauthorized military flights over Bosnia-Herzegovina. **Iraq.** In a status report on Iraq of May 24, President Clinton said that on April 9 and April 18 U.S. planes had bombed or fired missiles at Iraqi anti-aircraft sites that had tracked U.S. aircraft. **Somalia.** On June 10, 1993, President Clinton reported that in response to attacks against U.N. forces in Somalia by a factional leader, the U.S. Quick Reaction Force in the area had participated in military action to quell the violence. On July 1 President Clinton reported further air and ground military operations on June 12 and June 17 aimed at neutralizing military capabilities that had impeded U.N. efforts to deliver humanitarian relief and promote national reconstruction, and additional instances occurred in the following months. **Iraq.** On June 28, 1993, President Clinton reported that on June 26 U.S. naval forces had launched missiles against the Iraqi Intelligence Service's headquarters in Baghdad in response to an unsuccessful attempt to assassinate former President Bush in Kuwait in April 1993. **Iraq.** In a status report of July 22, 1993, President Clinton said on June 19 a U.S. aircraft had fired a missile at an Iraqi anti-aircraft site displaying hostile intent. U.S. planes also bombed an Iraqi missile battery on August 19, 1993. **Macedonia.** On July 9, 1993, President Clinton reported the deployment of 350 U.S. soldiers to the former Yugoslav Republic of Macedonia to participate in the U.N. Protection Force to help maintain stability in the area of former Yugoslavia.

	Haiti. On October 20, 1993, President Clinton reported that U.S. ships had begun to enforce a U.N. embargo against Haiti.
1994	**Bosnia.** On February 17, 1994, President Clinton reported that the United States had expanded its participation in United Nations and NATO efforts to reach a peaceful solution to the conflict in former Yugoslavia and that 60 U.S. aircraft were available for participation in the authorized NATO missions. **Bosnia.** On March 1, 1994, President Clinton reported that on February 28 U.S. planes patrolling the "no-fly zone" in former Yugoslavia under NATO shot down four Serbian Galeb planes. **Bosnia.** On April 12, 1994, President Clinton reported that on April 10 and 11, U.S. warplanes under NATO command had fired against Bosnian Serb forces shelling the "safe" city of Gorazde. **Rwanda**. On April 12, 1994, President Clinton reported that combat-equipped U.S. military forces had been deployed to Burundi to conduct possible non-combatant evacuation operations of U.S. citizens and other third-country nationals from Rwanda, where widespread fighting had broken out. By September 30, 1994, all U.S. troops had departed from Rwanda and surrounding nations. In the Defense Appropriations Act for FY1995 (P.L. 103-335, signed September 30, 1994), Congress barred use of funds for U.S. military participation in or around Rwanda after October 7, 1994, except for any action necessary to protect U.S. citizens. **Macedonia.** On April 19, 1994, President Clinton reported that the U.S. contingent in the former Yugoslav Republic of Macedonia had been augmented by a reinforced company of 200 personnel. **Haiti.** On April 20, 1994, President Clinton reported that U.S. naval forces had continued enforcement of the U.N. embargo in the waters around Haiti and that 712 vessels had been boarded since October 20, 1993. **Bosnia.** On August 22, 1994, President Clinton reported the use on August 5 of U.S. aircraft under NATO to attack Bosnian Serb heavy weapons in the Sarajevo heavy weapons exclusion zone upon request of the U.N. Protection Forces. **Haiti.** On September 21, 1994, President Clinton reported the deployment of 1,500 troops to Haiti to restore democracy in Haiti. The troop level was subsequently increased to 20,000. **Bosnia.** On November 22, 1994, President Clinton reported the use of U.S. combat aircraft on November 21, 1994, under NATO, to attack bases used by Serbs to attack the town of Bihac in Bosnia. **Macedonia**. On December 22, 1994, President Clinton reported that the U.S. Army contingent in the former Yugoslav Republic of Macedonia continued its peacekeeping mission and that the current contingent would soon be replaced by about 500 soldiers from the 3rdBattalion, 5thCavalry Regiment, and 1st Armored Division from Kirchgoens, Germany.
1995	**Somalia.** On March 1, 1995, President Clinton reported that on February 27, 1995, 1,800 combat-equipped U.S. Armed Forces personnel began deployment into Mogadishu, Somalia, to assist in the withdrawal of U.N. forces assigned there to the United Nations Operation in Somalia (UNOSOM II). This mission was completed on March 3, 1995.

	Haiti. On March 21, 1995, President Clinton reported that U.S. military forces in Haiti as part of a U.N. Multinational Force had been reduced to just fewer than 5,300 personnel. He noted that as of March 31, 1995, approximately 2,500 U.S. personnel would remain in Haiti as part of the U.N. Mission in Haiti (UNMIH). **Bosnia.** On May 24, 1995, President Clinton reported that U.S. combat-equipped fighter aircraft and other aircraft continued to contribute to NATO's enforcement of the no-fly zone in airspace over Bosnia-Herzegovina. U.S. aircraft, he noted, were also available for close air support of U.N. forces in Croatia. Roughly 500 U.S. soldiers continued to be deployed in the former Yugoslav Republic of Macedonia as part of the U.N. Preventive Deployment Force (UNPREDEP). U.S. forces continued to support U.N. refugee and embargo operations in this region. **Bosnia.** On September 1, 1995, President Clinton reported that "U.S. combat and support aircraft" had been used beginning on August 29, 1995, in a series of NATO air strikes against Bosnian Serb Army (BSA) forces in Bosnia-Herzegovina that were threatening the U.N.-declared safe areas of Sarajevo, Tuzla, and Gorazde. He noted that during the first day of operations, "some 300 sorties were flown against 23 targets in the vicinity of Sarajevo, Tuzla, Gorazde and Mostar." **Haiti.** On September 21, 1995, President Clinton reported that currently the United States had 2,400 military personnel in Haiti as participants in UNMIH. In addition, 260 U.S. military personnel were assigned to the U.S. Support Group Haiti. **Bosnia.** On December 6, 1995, President Clinton reported to Congress that he had "ordered the deployment of approximately 1,500 U.S. military personnel" to Bosnia-Herzegovina and Croatia as part of a NATO "enabling force" to lay the groundwork for the prompt and safe deployment of the NATO-led Implementation Force (IFOR)," which would be used to implement the Bosnian peace agreement after its signing. The President also noted that he had authorized deployment of roughly 3,000 other U.S. military personnel to Hungary, Italy, and Croatia to establish infrastructure for the enabling force and the IFOR. **Bosnia.** On December 21, 1995, President Clinton reported to Congress that he had ordered the deployment of approximately 20,000 U.S. military personnel to participate in IFOR in the Republic of Bosnia-Herzegovina, and approximately 5,000 U.S. military personnel would be deployed in other former Yugoslav states, primarily in Croatia. In addition, about 7,000 U.S. support forces would be deployed to Hungary, Italy, and Croatia and other regional states in support of IFOR's mission.
1997	**Haiti.** On March 21, 1996, President Clinton reported to Congress that beginning in January 1996 there had been a "phased reduction" in the number of United States personnel assigned to UNMIH. As of March 21, 309 U.S. personnel remained a part of UNMIH. These U.S. forces were "equipped for combat." **Liberia.** On April 11, 1996, President Clinton reported to Congress that on April 9, 1996, due to the "deterioration of the security situation and the resulting threat to American citizens" in Liberia he had ordered U.S. military forces to evacuate from that country "private U.S. citizens and certain third-country nationals who had taken refuge in the U.S. Embassy compound."

	Liberia. On May 20, 1996, President Clinton reported to Congress the continued deployment of U.S. military forces in Liberia to evacuate both American citizens and other foreign personnel, and to respond to various isolated "attacks on the American Embassy complex" in Liberia. The President noted that the deployment of U.S. forces would continue until there was no longer any need for enhanced security at the embassy and a requirement to maintain an evacuation capability in the country. **Central African Republic.** On May 23, 1996, President Clinton reported to Congress the deployment of U.S. military personnel to Bangui, Central African Republic, to conduct the evacuation from that country of "private U.S. citizens and certain U.S. Government employees," and to provide "enhanced security for the American Embassy in Bangui." **Bosnia.** On June 21, 1996, President Clinton reported to Congress that United States forces totaling about 17,000 remain deployed in Bosnia "under NATO operational command and control" as part of the NATO Implementation Force (IFOR). In addition, about 5,500 U.S. military personnel were deployed in Hungary, Italy, and Croatia, and other regional states to provide "logistical and other support to IFOR." The President noted that it was the intention that IFOR would complete the withdrawal of all troops in the weeks after December 20, 1996, on a schedule "set by NATO commanders consistent with the safety of troops and the logistical requirements for an orderly withdrawal." He also noted that a U.S. Army contingent (of about 500 U.S. soldiers) remained in the Former Yugoslav Republic of Macedonia as part of the United Nations Preventive Deployment Force (UNPREDEP). **Rwanda and Zaire**. On December 2, 1996, President Clinton reported to Congress that to support the humanitarian efforts of the United Nations regarding refugees in Rwanda and the Great Lakes Region of Eastern Zaire, he had authorized the use of U.S. personnel and aircraft, including AC-130U planes to help in surveying the region in support of humanitarian operations, although fighting still was occurring in the area, and U.S. aircraft had been subject to fire when on flight duty. **Bosnia.** On December 20, 1996, President Clinton reported to Congress that he had authorized U.S. participation in an IFOR follow-on force in Bosnia, known as SFOR (Stabilization Force), under NATO command. The President said the U.S. forces contribution to SFOR was to be "about 8,500" personnel whose primary mission is to deter or prevent a resumption of hostilities or new threats to peace in Bosnia. SFOR's duration in Bosnia was expected to be 18 months, with progressive reductions and eventual withdrawal.
1998	**Albania**. On March 15, 1997, President Clinton reported to Congress that on March 13, 1997, he had utilized U.S. military forces to evacuate certain U.S. government employees and private U.S. citizens from Tirana, Albania, and to enhance security for the U.S. embassy in that city. **Congo and Gabon.** On March 27, 1997, President Clinton reported to Congress that, on March 25, 1997, a standby evacuation force of U.S. military personnel had been deployed to Congo and Gabon to provide enhanced security for

	American private citizens, government employees, and selected third country nationals in Zaire, and to be available for any necessary evacuation operation. **Sierra Leone.** On May 30, 1997, President Clinton reported to Congress that on May 29 and May 30, 1997, U.S. military personnel were deployed to Freetown, Sierra Leone, to prepare for and undertake the evacuation of certain U.S. government employees and private U.S. citizens. **Bosnia.** On June 20, 1997, President Clinton reported to Congress that U.S. Armed Forces continued to support peacekeeping operations in Bosnia and other states in the region in support of the NATO-led Stabilization Force (SFOR). He reported that currently most U.S. military personnel involved in SFOR were in Bosnia, near Tuzla, and about 2,800 U.S. troops were deployed in Hungary, Croatia, Italy, and other regional states to provide logistics and other support to SFOR. A U.S. Army contingent of about 500 also remained in the Former Yugoslav Republic of Macedonia as part of the UNPREDEP. **Cambodia.** On July 11, 1997, President Clinton reported to Congress that in an effort to ensure the security of American citizens in Cambodia during a period of domestic conflict there, he had deployed a Task Force of about 550 U.S. military personnel to U-Tapao Air Base in Thailand. These personnel were to be available for possible emergency evacuation operations in Cambodia as deemed necessary. **Bosnia.** On December 19, 1997, President Clinton reported to Congress that he intended "in principle" to have the United States participate in a security presence in Bosnia when the NATO SFOR contingent withdrew in the summer of 1998.
1998	**Guinea-Bissau.** On June 12, 1998, President Clinton reported to Congress that, on June 10, 1998, in response to an army mutiny in Guinea-Bissau endangering the U.S. embassy, U.S. government employees, and U.S. citizens in that country, he had deployed a standby evacuation force of U.S. military personnel to Dakar, Senegal, to remove such individuals, as well as selected third country nationals, from the city of Bissau. The deployment continued until the necessary evacuations were completed. **Bosnia.** On June 19, 1998, President Clinton reported to Congress regarding activities in the last six months of combat-equipped U.S. forces in support of NATO's SFOR in Bosnia and surrounding areas of former Yugoslavia. **Kenya and Tanzania.** On August 10, 1998, President Clinton reported to Congress that he had deployed, on August 7, 1998, Joint Task Force of U.S. military personnel to Nairobi, Kenya, to coordinate the medical and disaster assistance related to the bombings of the U.S. Embassies in Kenya and Tanzania. He also reported that teams of 50-100 security personnel had arrived in Nairobi, Kenya, and Dar es Salaam, Tanzania, to enhance the security of the U.S. Embassies and citizens there. **Albania.** On August 18, 1998, President Clinton reported to Congress that he had, on August 16, 1998, deployed 200 U.S. Marines and 10 Navy SEALS to the U.S. embassy compound in Tirana, Albania, to enhance security against reported threats against U.S. personnel. **Afghanistan and Sudan.** On August 21, 1998, by letter, President Clinton reported to Congress that he had authorized airstrikes on August 20 against camps and installations in Afghanistan and Sudan used by the Osama bin Laden

	terrorist organization. The President did so based on what he viewed as convincing information that the bin Laden organization was responsible for the bombings, on August 7, 1998, of the U.S. Embassies in Kenya and Tanzania. **Liberia.** On September 29, 1998, President Clinton reported to Congress that on September 27, 1998, he had, due to political instability and civil disorder in Liberia, deployed a stand-by response and evacuation force of 30 U.S. military personnel to augment the security force at the U.S. embassy in Monrovia, and to provide for a rapid evacuation capability, as needed, to remove U.S. citizens and government personnel from the country. **Iraq.** During the period from December 16-23, 1998, the United States, together with the United Kingdom, conducted a bombing campaign, termed Operation Desert Fox, against Iraqi industrial facilities deemed capable of producing weapons of mass destruction, and against other Iraqi military and security targets.
1998-1999	**Iraq.** Beginning in late December 1998, and continuing during 1999, the United States, together with forces of the coalition enforcing the "no-fly" zones over Iraq, conducted military operations against the Iraqi air defense system on numerous occasions in response to actual or potential threats against aircraft enforcing the "no-fly" zones in northern and southern Iraq.
1999	**Bosnia.** On January 19, 1999, President Clinton reported to Congress that he was continuing to authorize the use of combat-equipped U.S. Armed Forces in Bosnia and other states in the region as participants in and supporters of the NATO-led Stabilization Force (SFOR). He noted that the U.S. SFOR military personnel totaled about 6,900, with about 2,300 U.S. military personnel deployed to Hungary, Croatia, Italy, and other regional states. Also, some 350 U.S. military personnel remain deployed in the Former Yugoslav Republic of Macedonia (FYROM) as part of UNPREDEP. **Kenya.** On February 25, 1999, President Clinton reported to Congress that he was continuing to deploy U.S. military personnel in that country to assist in providing security for the U.S. embassy and American citizens in Nairobi, pending completion of renovations of the American embassy facility in Nairobi, subject of a terrorist bombing in August 1998. **Yugoslavia.** On March 26, 1999, President Clinton reported to Congress that, on March 24, 1999, U.S. military forces, at his direction, and in coalition with NATO allies, had commenced air strikes against Yugoslavia in response to the Yugoslav government's campaign of violence and repression against the ethnic Albanian population in Kosovo. **Yugoslavia/Albania.** On April 7, 1999, President Clinton reported to Congress that he had ordered additional U.S. military forces to Albania, including rotary wing aircraft, artillery, and tactical missiles systems to enhance NATO's ability to conduct effective air operations in Yugoslavia. About 2,500soldiers and aviators are to be deployed as part of this task force. The President also reported the deployment of U.S. military forces to Albania and Macedonia to support humanitarian disaster relief operations for Kosovar refugees. **Yugoslavia/Albania**. On May 25, 1999, President Clinton reported to Congress, "consistent with the war Powers Resolution," that he had directed "deployment of additional aircraft and forces to support NATO's ongoing efforts [against

	Yugoslavia], including several thousand additional U.S. Armed Forces personnel to Albania in support of the deep strike force located there." He also directed that additional U.S. forces be deployed to the region to assist in "humanitarian operations." **Yugoslavia/Kosovo.** On June 12, 1999, President Clinton reported to Congress, "consistent with the War Powers Resolution," that he had directed the deployment of about "7,000 U.S. military personnel as the U.S. contribution to the approximately 50,000-member, NATO-led security force (KFOR)" currently being assembled in Kosovo. He also noted that about "1,500 U.S. military personnel, under separate U.S. command and control, will deploy to other countries in the region, as our national support element, in support of KFOR." **Bosnia.** On July 19, 1999, President Clinton reported to Congress, "consistent with the War Powers Resolution," that about 6,200 U.S. military personnel were continuing to participate in the NATO-led Stabilization Force (SFOR) in Bosnia, and that another 2,200 personnel were supporting SFOR operations from Hungary, Croatia, and Italy. He also noted that U.S. military personnel remain in the Former Yugoslav Republic of Macedonia to support the international security presence in Kosovo (KFOR). **East Timor.** On October 8, 1999, President Clinton reported to Congress "consistent with the War Powers Resolution" that he had directed the deployment of a limited number of U.S. military forces to East Timor to support the U.N. multinational force (INTERFET) aimed at restoring peace to East Timor. U.S. support has been limited initially to "communications, logistics, planning assistance and transportation." The President further noted that he had authorized deployment of the amphibious ship USS Belleau Wood, together with its helicopters and her complement of personnel from the 31stMarine Expeditionary Unit (Special Operations Capable) (MEU SOC), to the East Timor region, to provide helicopter airlift and search and rescue support to the multinational operation. U.S. participation was anticipated to continue until the transition to a U.N. peacekeeping operation was complete. **Yugoslavia/Kosovo.** On December 15, 1999, President Clinton reported to Congress "consistent with the War Powers Resolution" that U.S. combat-equipped military personnel continued to serve as part of the NATO-led security force in Kosovo (KFOR). He noted that the American contribution to KFOR in Kosovo was "approximately 8,500 U.S. military personnel." U.S. forces were deployed in a sector around Uroševac (Ferizaj) in the eastern portion of Kosovo." For U.S. KFOR forces, "maintaining public security is a key task." Other U.S. military personnel are deployed to other countries in the region to serve in administrative and logistics support roles for U.S. forces in KFOR. Of these forces, about 1,500 U.S. military personnel are in Macedonia and Greece, and occasionally in Albania.
1999-2000	**Iraq.** At various times during 1999, and continuing throughout 2000, the United States, together with forces of the coalition enforcing the "no-fly" zones over Iraq, conducted military operations against the Iraqi air defense system on numerous occasions in response to actual or potential threats against aircraft enforcing the "no-fly" zones in northern and southern Iraq.

2000	**Bosnia.** On January 25, 2000, President Clinton reported to Congress "consistent with the War Powers Resolution" that the United States continued to provide combat-equipped U.S. Armed Forces to Bosnia-Herzegovina and other states in the region as part of the NATO led Stabilization Force (SFOR). The President noted that the U.S. force contribution was being reduced from "approximately 6,200 to 4,600 personnel," with the U.S. forces assigned to Multinational Division, North, around the city of Tuzla. He added that approximately 1,500 U.S. military personnel were deployed to Hungary, Croatia, and Italy to provide "logistical and other support to SFOR"and U.S. forces continue to support SFOR in "efforts to apprehend persons indicted for war crimes." **East Timor**. On February 25, 2000, President Clinton reported to Congress "consistent with the War Powers Resolution" that he had authorized the participation of a small number of U.S. military personnel in support of the United Nations Transitional Administration in East Timor (UNTAET), which has a mandate to maintain law and order throughout East Timor, and to facilitate establishment of an effective administration there, delivery of humanitarian assistance, and support the building of self-government. The President reported that the U.S. contingent was small: three military observers, and one judge advocate. To facilitate and coordinate U.S. military activities in East Timor, the President also authorized the deployment of a support group (USGET), consisting of 30 U.S. personnel. U.S. personnel would be temporarily deployed to East Timor, on a rotational basis, and through periodic ship visits, during which U.S. forces would conduct "humanitarian and assistance activities throughout East Timor." Rotational activities should continue through the summer of 2000. **Sierra Leone.** On May 12, 2000, President Clinton, "consistent with the War Powers Resolution," reported to Congress that he had ordered a U.S. Navy patrol craft to deploy to Sierra Leone to be ready to support evacuation operations from that country if needed. He also authorized a U.S. C-17 aircraft to deliver "ammunition, and other supplies and equipment" to Sierra Leone in support of United Nations peacekeeping operations there. **Yugoslavia/Kosovo**. On June 16, 2000, President Clinton reported to Congress, "consistent with the War Powers Resolution," that the United States was continuing to provide military personnel to the NATO-led KFOR security force in Kosovo. U.S. forces were numbered at 7,500 but were scheduled to be reduced to 6,000 when ongoing troop rotations were completed. U.S. forces in Kosovo are assigned to a sector centered near Gnjilane (Gjilan)in eastern Kosovo. Other U.S. military personnel are deployed to other countries serving in administrative and logistics support roles, with approximately 1,000 U.S. personnel in Macedonia, Albania, and Greece. **Bosnia.** On July 25, 2000, President Clinton reported to Congress, "consistent with the War Powers Resolution," that combat-equipped U.S. military personnel continued to participate in the NATO-led Stabilization Force (SFOR) in Bosnia-Herzegovina, being deployed to Bosnia and other states in the region in support of peacekeeping efforts in former Yugoslavia. U.S. military personnel levels have been reduced from 6,200 to 4,600. Apart from the forces in Bosnia,

	approximately 1,000 U.S. personnel continue to be deployed in support roles in Hungary, Croatia, and Italy. East **Timor.** On August 25, 2000, President Clinton reported to Congress, "consistent with the War Powers Resolution," that the United States was currently contributing three military observers to the United Nations Transitional Administration in East Timor (UNTAET) that is charged by the U.N. with restoring and maintaining peace and security there. He also noted that the United States was maintaining a military presence in East Timor separate from UNTAET, comprised of about 30 U.S. personnel who facilitate and coordinate U.S. military activities in East Timor and rotational operations of U.S. forces there. U.S. forces currently conduct humanitarian and civic assistance activities for East Timor's citizens. U.S. rotational presence operations in East Timor are presently expected, the President said, to continue through December 2000. **Yemen.** On October 14, 2000, President Clinton reported to Congress, "consistent with the War Powers Resolution," that on October 12, 2000, in the wake of an attack on the USS Cole in the port of Aden, Yemen, he had authorized deployment of about 45 military personnel from U.S. Naval Forces Central Command to Aden to provide "medical, security, and disaster response assistance." The President further reported that on October 13, 2000, about 50 U.S. military security personnel arrived in Aden, and that additional "security elements" may be deployed to the area, to enhance the ability of the U.S. to ensure the security of the USS Cole and the personnel responding to the incident. In addition, two U.S. Navy surface combatant vessels are operating in or near Yemeni territorial waters to provide communications and other support, as required. **Yugoslavia/Kosovo.** On December 18, 2000, President Clinton reported to Congress, "consistent with the War Powers Resolution," that the United States was continuing to provide approximately 5,600 U.S. military personnel in support of peacekeeping efforts in Kosovo as part of KFOR. An additional 500 U.S. military personnel are deployed as the National Support Element in Macedonia, with an occasional presence in Albania and Greece. U.S. forces are assigned to a sector around Gnjilane in the eastern portion of Kosovo. The President noted that the mission for these U.S. military forces is maintaining a safe and secure environment through conducting "security patrols in urban areas and in the countryside throughout their sector."

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