

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

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## ABSTRACT

This paper takes an interdisciplinary approach to understanding what makes nation-states antifragile and why this matters. Antifragility is a nascent concept, coined in 2005 by Nicholas Nassim Taleb in his book *Foiled by Randomness: The Hidden Role of Chance in Life and in the Markets*. Later, in 2015, in a Foreign Affairs article by Nicholas Nassim Taleb and Gregory Treverton, the authors outline five characteristics of nation-state antifragility. These include: concentrated decision making, political variability, economic diversity, debt to leverage ratio, and history of surviving past shocks. The following paper advances the study of antifragility beyond the initial contributions of Taleb and Treverton by (1) development of three propensity variables associated with nation-state antifragility (agility, learning, and power conversion); (2) a new agent-based model to investigate antifragility; and (3) applying the findings of the agent-based model to a unique case study. The three variables mentioned above compromise a nation-state's capacity for dealing with various stressors in the international environment. The agent-based model in this paper captures the behavior of a single, nation-state when confronted with stress in a variety of scenarios, forming an essential building block for future work involving interaction between nation-states.

## ABOUT THE AUTHOR

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### INTRODUCTION

From the September 11, 2001 terrorist attacks through a housing crash unanticipated by risk models, to the COVID-19 pandemic, and the unprecedented response to it, there are ample grounds for the claim that state survival and success depend, in part, on creative responses. Nation-states that successfully navigate this burgeoning new world order, while trying to make sense of it, do so in ways that are neither fixed nor linear. In fact, success is dependent upon nation-states possessing a trinity of characteristics: agility, learning, and the ability to convert power. In other words, they are antifragile.

Nicholas Nassim Taleb first coined the term “antifragile” in his book *Fooled by Randomness: The Hidden Role of Chance in Life in the Markets* (2005). He described it thus, “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.” In 2015, Nicholas Nassim Taleb and Gregory Treverton expanded antifragility beyond economics and applied it to nation-states as a way to explain unanticipated outcomes in international affairs in their Foreign Affairs article, “The Calm Before the Storm: Why Volatility Signals Stability, and Vice Versa.”

At first glance, antifragility possesses a counterintuitiveness about it. Taleb and Treverton aptly point out how stability can paradoxically signal fragility and chaos can signal strength. As international relations scholars and foreign policy practitioners seek to better understand the organization and mechanism behind nation-state behavior, along with the ways in which nation-states adapt successfully or unsuccessfully to the challenges and problems they encounter over time, the counterintuitive concept of antifragility may help enhance current theoretical paradigms that fail to account for these unanticipated and often curious outcomes.

Through the lens of a new paradigm, such as antifragile nation-states, the global political order looks vastly different. Nation-states once perceived as resilient and seemingly stable may in fact be weaker when faced with a particular set of stressors in the international environment. Conversely, nation-states presently perceived as weak or failed may in fact be more resilient or even antifragile over time. As I write this paper one hundred days into Russia’s war in Ukraine, we find that Ukraine has confounded many who believed the conflict would not have lasted as long as it did or that Ukraine would have been as successful as it has been against the Russian military. Antifragility can explain Ukraine’s formidable performance in this conflict, including the qualities and characteristics that have allowed Ukraine to successfully adapt to the challenges it faces.

In this paper I posit that there is a common set of properties that bind such nation-states such as Ukraine. That is, they are more agile in traversing uncertainty; they are better at learning from their experiences; and they are better able at converting power in a complex environment.

But why are some nation-states more antifragile than others, and what difference does this make?

## METHODOLOGY

Informed by the nascent literature on antifragility, I have identified three unique propensity variables: agility, learning, and power conversion. Under certain conditions, these variables reap fragile, resilient, or antifragile outcomes. Next, an agent-based model of a single nation-state facing shocks was developed using Netlogo to explore the difference antifragility makes for nation-state survival and state power in addition to exploring the links between challenging environments and the development or maintenance of antifragility. Developed by Uri Wilensky, NetLogo is a multi-agent programmable modeling environment that is used predominantly for agent-based modeling worldwide.

### Agility

Nation-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. Overall, the process by which a state becomes agile is one in which they 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. That is, learning is an integral part of the development of a state's agility.

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. The more centrally concentrated the decision-making process is within a government, the more fragile the state; conversely, the less concentrated the decision-making process is, the more antifragile the state (Taleb and Treverton, 2015).

Complementing the idea of concentrated decision making is the notion of political variability, as it is necessary in order to have a diffused decision-making apparatus. The greater the political variability, the more antifragile a state is (Taleb and Treverton, 2015). Conversely, the less politically variable, the more fragile the state (Taleb and Treverton, 2015).

### Learning

The process of exercising judgment based on an experience or some other kind of input that leads actors to select a different view of how things happen and what courses of action should be taken. States learn by trying out new ideas and methods, choosing those that work and 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.

### Power Conversion

Power conversion is defined as getting from resources to behavioral outcomes. Power, like that of fragility, resides along a spectrum. According to Joseph Nye in *The Future of Power*, "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." The action portion of the term power conversion, or conversion, implicitly means the process to change or to cause something from one form to 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.

## THE MODEL

The agent-based model can be broken down into its three constituent parts: the agent, the environment, and the interaction between the agent and the environment. To summarize the model, a single agent (state) interacts with shocks (red patches in Netlogo visualization) throughout the simulation environment at random. States are endowed with a set of characteristics, informed by the literature and three propensity variables (Table 1).

Table 1. The Evolution of the Characteristics of The Agent

Original Variables (Taleb and Treverton, 2015)	Propensity Variable	Final Model Variable	Definition of Final Model Variable
1. Concentrated Decision Making	Agility	Recovery Time	The amount of time it takes a state to recover from a shock
2. Political Variability		Recovery Magnitude	The extent to which a state recovers
3. Economic Diversity	Power Conversion	Performance	The ability of a state to absorb stress without dying
4. Debt to Leverage Ratio		Capacity	The defining characteristic of a state's type: fragile, resilient, or antifragile
5. History of Surviving Past Shocks	Learning	Learning Forgetfulness	The ability of a state to learn from its previous experiences and its capacity. The forgetfulness of the state of its previous experiences.

When the agent interacts with a shock, a series of internal processes by the state is undertaken. Briefly, as a result of this process, antifragile states become stronger, resilient states return to their initial status, and fragile states become weaker (Figure 1 and Figure 2). In some simulations, interactions 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 fragile. 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 poised to produce antifragile outcomes.

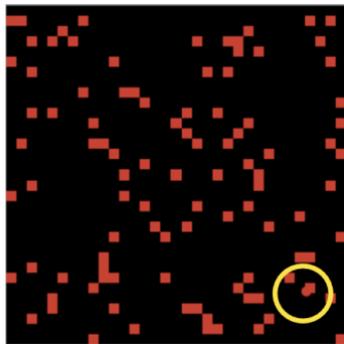


Figure 1. Example of a fragile agent in the simulation environment

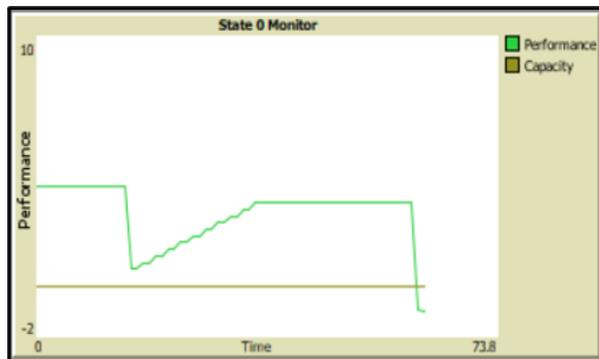


Figure 2. Example of a fragile agent's performance

### Verification and Validation

While verification and validation occur at various points throughout the modeling process, this paper highlights verification and validation at three points throughout the model development life cycle: conceptual model, computerized model, and operational model development phases.

The verification techniques chosen for the conceptual modeling stage are those that come from informal categories, specifically walkthrough. Walkthroughs are the most time-consuming and most formal of the informal methods. For the purpose of this paper, the primary validation techniques used for the conceptual model 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 paper 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.

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 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.

According to Whitner and Balci (1989), "any model that is to undergo translation from a higher form to a machine-readable form must first pass a syntax test." 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.

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 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 is 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 (2009), "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."

## EXPERIMENTAL DESIGN

The experimental design consists of two world types. World A is a static model and focused on providing insights into how antifragility is important for state survival. In this world, capacity is fixed, rendering a static model in which 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 experimental design in World A is an  $8 \times 4 \times 10 \times 4$  factorial design with 12,800 unique combinations of variable values. The initialization parameters for World A are summarized in Table 2.

Table 2. World A Initialization Parameters

Agent Variable	Initialization Parameter Value(s)
Capacity	(1, 16), increments of 5
Performance	(1, 20), increments of 2
Recovery Time	(1, 20), increments of 2
Gamma Variance	(1, 10), increments of 3
Number of Shocks	(1, 200) increments of 25
Percent-Learn	0

Percent-Forget	0
Gamma Mean	5

World B is a dynamic model that examines what kind of world is going to be best for state survival and maintaining antifragility. In this world, the agent's state capacity does change. That is, states can 'learn' to have a higher capacity and become (more) antifragile. Conversely, they can forget their existing capacity and become (more) fragile. In World B, the agent's *percent-learn* and *percent-forget* variables are greater than 0. The structure of the experiments and the results of these experiments underscore 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 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. The initialization parameters for World B are summarized in Table 3.

Table 3. World B Initialization Parameters

Agent Variable	Initialization Parameter Value(s)
Capacity	(1, 16), increments of 5
Performance	(1, 20), increments of 2
Recovery Time	(1, 20), increments of 2
Gamma Variance	(1, 10), increments of 3
Number of Shocks	(1, 200) increments of 25
Percent-Learn	(0.01, 0.2), increments of 0.02
Percent-Forget	(0.01, 0.2), increments of 0.02
Gamma Mean	5

## SELECTED RESULTS AND ANALYSIS

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.

### Initial Performance

In World A, life length is short for all states with a low initial performance, and the antifragile really benefits from an increase in initial performance (Figure 3). In World B, an increase in initial performance increases life length for all state types (Figure 4).

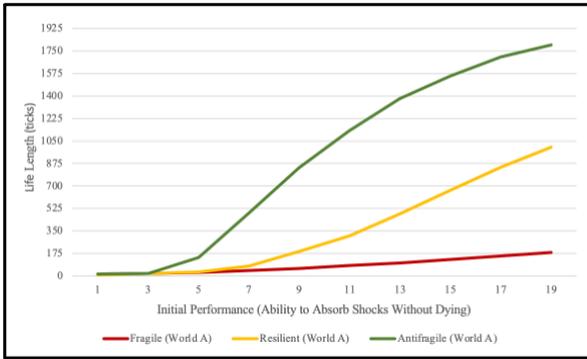


Figure 3. World A: Impact of Antifragility, Resilience, and Fragility on Life Length with Respect to Initial Performance Value

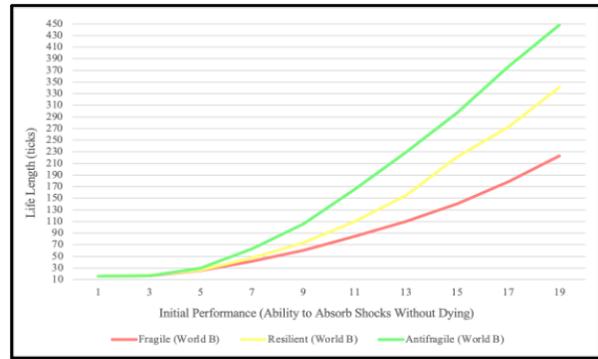


Figure 4. World B: Impact of Initial Antifragility, Resilience, and Fragility on Life Length with Respect to Initial Performance Value

### Recovery Time

In World A, an increase in recovery time decreases the life length of each state type (Figure 5). In World B, an increase in recovery time decreases life length in the fragile and resilient state type. The antifragile state benefits from a longer recovery time during the period between 5 and 11 (Figure 6).

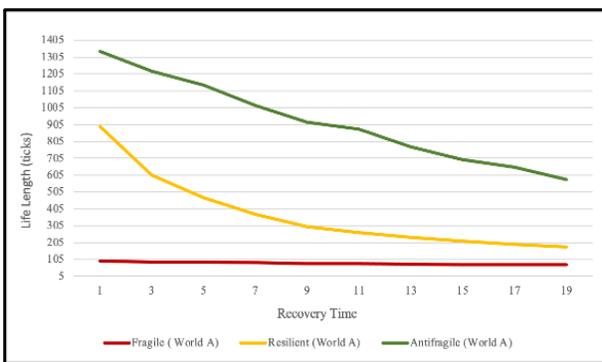


Figure 5. World A: Impact of Antifragility, Resilience and Fragility on Life Length with Respect to Recovery Time

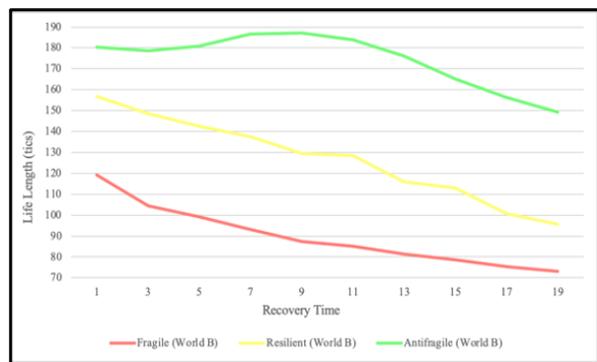


Figure 6. World B: Impact of Initial Antifragility, Resilience, and Fragility on Life Length with Respect to Recovery Time

### Number of Shocks

In World A, the life length of each state type decreases with an increase in the number of shocks (Figure 7). In World B, the life length of the fragile and resilience state types decrease with an increase in the number of shocks. The antifragile life length increases with an increase in the number of shocks (Figure 8).

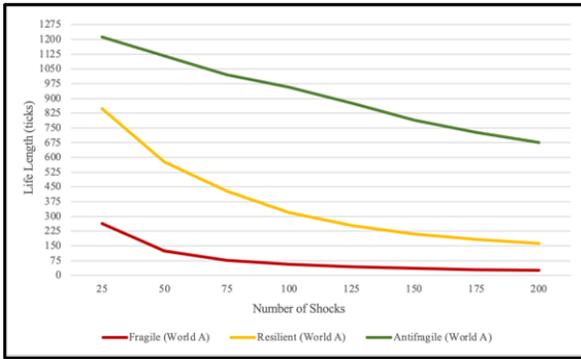


Figure 7. World A: Impact of Antifragility, Resilience, and Fragility on Life Length with Respect to Number of Shocks

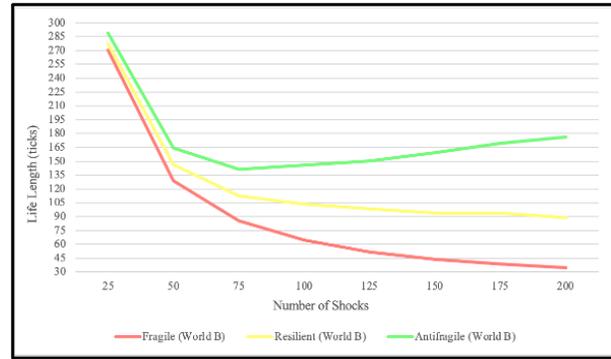


Figure 8. World B: Impact of Initial Antifragility, Resilience, and Fragility on Life Length with Respect to Number of Shocks

### Learning and Forgetting of Antifragility Capacity

In World B, all state types' life length decreases with an increase in forgetfulness (Figure 9). Additionally, the life length of all state types increases with an increase in learning (Figure 10).

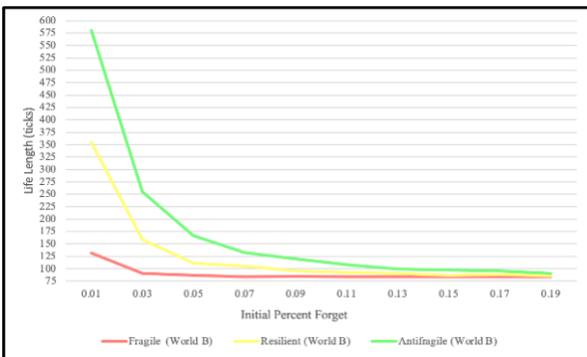


Figure 9. World A: Impact of Initial Antifragility, Resilience, and Fragility on Life Length with Respect to Forgetfulness

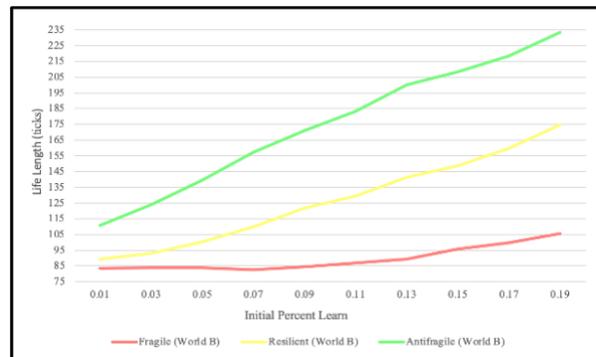


Figure 10. World B: Impact of Initial Antifragility, Resilience, and Fragility on Performance with Respect to Learning

### Number of Shocks' Impact on Performance

In World A, though life length decreased, with respect to an increase in the number of shocks, the final average performance increased for antifragile states and decreased for fragile and resilient states (Figure 11). In World B, both life length and final average performance increase for all state types (Figure 12). Furthermore, the results from World B reveal that the 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 increases with respect to an increase in the number of shocks, demonstrating how the antifragile gains from volatility (Taleb and Treverton, 2015).

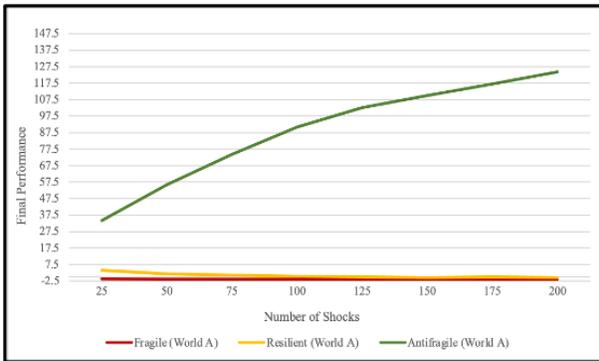


Figure 11. World A: Impact of Antifragility, Resilience, and Fragility on Performance with Respect to the Number of Shocks

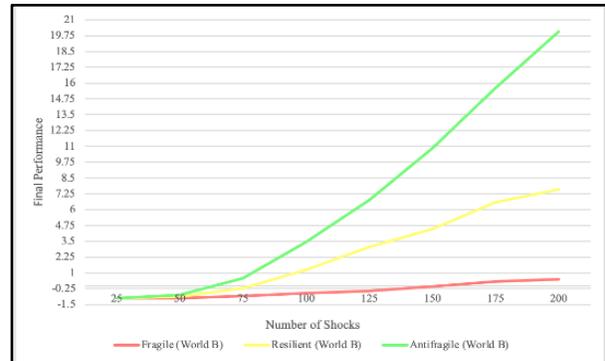


Figure 12. World B: Impact of Initial Antifragility, Resilience, and Fragility on Performance with Respect to the Number of Shocks

## RESULTS IMPLICATIONS

With the results presented, it is helpful to note that 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 antifragility is important to state power and state survival, specifically in the model with respect to the dependent variable, life length.

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 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 nation-states (hereafter referred to as "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 and 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. Upon 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 by having knowledge of which stressors may benefit them.

## MODEL LIMITATIONS

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 occurs 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 shock 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. 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 limited. 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 and more 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.

Finally, 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.

## **IMPLICATIONS FOR FOREIGN POLICY**

There are three primary implications for this work with regard to foreign policy. First, the research presented in this paper provides a methodological and conceptual contribution to foreign policy by enhancing the current measures of fragility/antifragility by identifying three propensity variables that may give rise to fragile, resilient, and antifragile outcomes of states. Through the consideration of these propensity variables 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 “sleepers” in the next global shock, which, in turn, could alter how we think about power-politics, the political world order, security, and deterrence.

Second, state antifragility could provide a blueprint for creating, organizing, and structuring state institutions and 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 of international organizations and institutions. 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 of a more antifragile one.

The final key implication of this study involves the ways in which states should think about antifragility in their relations with each other. The problem of the antifragile adversary comes into question and shows how in the face of such an adversary deterrence is particularly difficult. What strategies might one 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 benefit. 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.

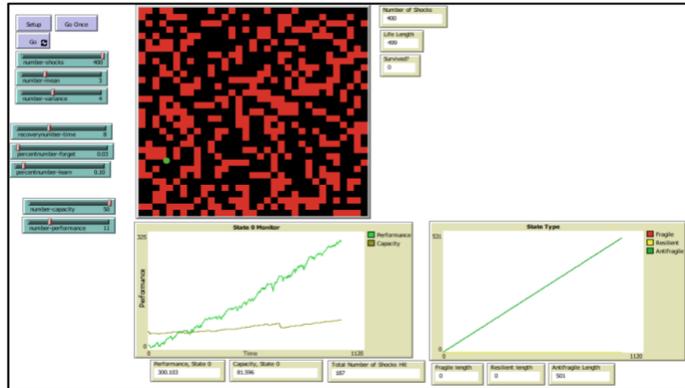


Figure 13. Antifragile state with high level of performance relative to shock mean

The simplest intuition about deterrence is that it is possible by threatening large enough costs that the adversary is dissuaded from taking a risk. But this strategy is sometimes difficult to implement against an antifragile adversary. If the structure of their payoff function is such that they will ultimately benefit from conflict, threatening conflict will hardly dissuade an actor from aggression.

Consider the following model runs. The state being modeled is very antifragile initially and has a high level of performance relative to the mean shock (Table 4). If nothing changes, this state will likely keep growing stronger, as shown in Figure 13.

Table 4. Agent and Environment Initialization Parameters

Agent Variable	Initialization Parameter Value(s)	Environment Variable	Initialization Parameter Value(s)
Performance	11	Gamma Mean	3
Capacity	50	Gamma Variance	4
Agent Type	Antifragile	Number of Shocks	400
Percent-Learn	0.10		
Percent-Forget	0.03		
Recovery Time	8		

What might be done? One surprising partial solution is actually to take away shocks from the state (Table 5). With all other parameters kept constant, the state transitions to become fragile with these parameters simply because it faces fewer shocks (Table 5 and Figure 14). Even better is to reduce the number but increase the severity of the shocks (Table 6 and Figure 15).

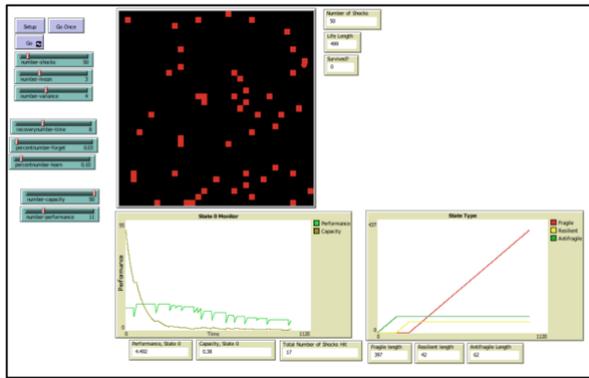


Figure 14. Antifrangible state with high level of performance relative to shock mean with fewer shocks

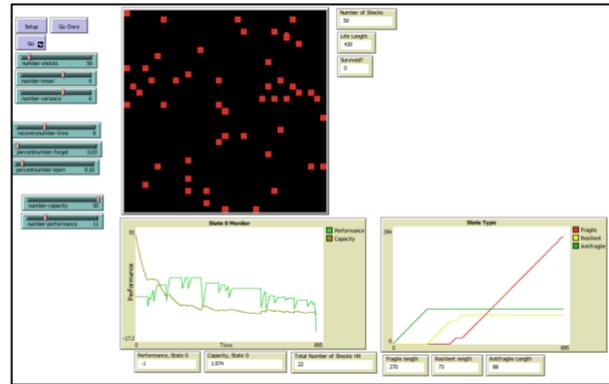


Figure 15. Reduced shock severity

Table 5. Agent and Environment Initialization Parameters

Agent Variable	Initialization Parameter Value(s)	Environment Variable	Initialization Parameter Value(s)
Performance	11	Gamma Mean	3
Capacity	50	Gamma Variance	4
Agent Type	Antifrangible	Number of Shocks	50
Percent-Learn	0.10		
Percent-Forget	0.03		
Recovery Time	8		

Table 6. Agent and Environment Initialization Parameters

Agent Variable	Initialization Parameter Value(s)	Environment Variable	Initialization Parameter Value(s)
Performance	11	Gamma Mean	6
Capacity	50	Gamma Variance	6
Agent Type	Antifrangible	Number of Shocks	50
Percent-Learn	0.10		
Percent-Forget	0.03		
Recovery Time	8		

Frequent but targeted penalties may be required. Frequency and severity together are important and potentially effective in deterring an antifrangible adversary.

Alternatively, an important strategy could be a search for the areas and aspects in which the putatively antifrangible regime is in fact fragile. Where are its vulnerabilities? Are there propaganda, economic, cyber, or territorial weaknesses that can be exploited in ways that truly weaken the regime that bypass and undermine the aspects of its position that are antifrangible?

If this is not a viable strategy, then strategies that cope with the aspects of an opponent's regime that are antifrangible over a longer time horizon are necessary. One key is to develop ideas and responses that make one's own

side more antifragile. An initial first step involves moving beyond the emphasis on resilience discussed in the literature review to focuses on a capacity to come back better from challenges.

## CONCLUSION

In conclusion, the theoretical model of state antifragility presented in this paper 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 of state behavior when exploring why some states fair better under stress than others, *ceteris paribus*. 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 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.

By creating an explicit, theoretical model, others are encouraged to challenge the assumptions and evolve the model to advance it from the theoretical to the practical.

## REFERENCES

- 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>.
- Nye Jr. Joseph, S. *The Future of Power*. New York, NY: Public Affairs, 2011.
- Sokolowski, John A., and Catherine M. Banks, eds. *Principles of Modeling and Simulation: A Multidisciplinary Approach*. Hoboken, NJ: Wiley, 2009.
- Taleb, Nassim Nicholas. *Antifragile: Things That Gain from Disorder*. New York, NY: Random House, 2014.
- Taleb, Nassim Nicholas. *Foiled by Randomness: The Hidden Role of Chance in Life and in the Markets*. New York, New York: Thomson/Texere, 2004.
- 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>.
- Whitner, Richard and Osman Balci. “Guidelines for Selecting and Using Simulation Model Verification Techniques” (1989), p. 9, retrieved from: <https://vtechworks.lib.vt.edu/bitstream/handle/10919/19511/TR-89-17.pdf?sequence=3&isAllowed=y>.