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# Hunting Gray Rhinos and Black Swans: Statistical and Machine Learning Models of Political Stability and Terrorism

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# Table of Contents

# Hunting Gray Rhinos and Black Swans: Statistical and Machine Learning Models of Political Stability and Terrorism

## Executive Summary

Strategic surprise, the realization that one's knowledge and assumptions are wrong and the adversary has an upper hand, is a national security nightmare (Amidon, 2005; Defense Science Board, 2015; Handel, 1984). Classic examples include Pearl Harbor, Sputnik, the Cuban Missile Crisis, and the September 11, 2001 terror attacks. This report addresses two types of surprises, Black Swans and Gray Rhinos. Black Swans are surprising, high-impact events produced by complex systems of non-linear interactions that are inherently unpredictable. In contrast, Gray Rhinos are surprising events whose indicators exist and should have been obvious but were missed because we were not looking or properly assessing them. This report presents statistical models that identify the drivers of Gray Rhino events and provide insight into Black Swan events in the USCENTCOM area of responsibility (AOR). Political instability and terrorism are the two types of events modeled.

**Political Stability**

- Corruption is the primary factor that undermines the political stability of USCENTCOM AOR countries. US government (USG) efforts to monitor corruption are, therefore, critical for providing indicators and warnings (I&W) of instability; US influence has the potential to decrease corruption.
- Insecurity in basic needs are an important source of instability in the USCENTCOM AOR. Water resources are finite and dwindling in the region and both water availability and hunger are associated with political instability. Food and water availability and food prices provide indicators of approaching instabilities that could threaten US interests in the region. Severe droughts or rapid fluctuations in the world food market have the potential to create Black Swan-like spikes in political instability. Such a spike, for example, contributed to the onset of the Syrian civil war.
- The models reveal that competition among elites in USCENTCOM AOR countries is a risk factor for instability. Elites who feel that the established political system is not serving their aspirations are the most likely source of disruption. Despite popular protests, rank-and-file populations do not have the means to mount an effective challenge to their governments. However, elites can use grievances, such as lack of basic needs, to mobilize the masses when convenient. USG efforts to influence elites, therefore, may be particularly effective in preventing social instability.
- Rugged terrain is associated with political instability, and many of the countries in the USCENTCOM AOR have such terrain.

**Terrorism**

- By far the leading factor in associated with terrorism in the USCENTCOM AOR is physically abusive state terror. Highly autocratic regimes are able to suppress terrorism in their own countries; however, if they use physically abusive means, they may be spawning terrorism abroad because such means are associated with terrorism.
- Corruption is strongly associated with terrorism in the USCENTCOM AOR. USG efforts to counteract corruption should, therefore, help to limit terrorism in the region.

- As USCENTCOM AOR countries democratize, terrorists are better able to operate. Democracy is associated with increased political stability in the region but may paradoxically increase terrorism.
- In the USCENTCOM AOR, the combination of a young population and high unemployment is associated with terrorism. Efforts to boost employment should help alleviate terrorism.
- The presence of war resulting in high battle deaths in the population is strongly associated with terrorism. US efforts to prevent war in the region should help to counter terrorism.

# Introduction

The concept of Black Swans was introduced by Nassim Taleb in 2007 to characterize events that are extreme outliers, have high impact, and that people have a tendency to explain after the fact. Black Swan events are inherently unpredictable, and Taleb (2007, p. 129) invokes chaos theory to explain why these phenomena cannot be predicted; because of non-linear relationships between variables, small inputs have disproportionate effects that have a tendency to spiral out of control. Taleb's suggestions are relevant for understanding national security threats such as political instability and terrorism. For instance, complexity theorists have applied his notion to develop formal models for the sudden eruption of social conflict from non-linear interactions between individual competition over wealth and government policy (Bellomo, Herrero, & Tosin, 2013).

Contrasting Taleb, Michele Wucker (2016) points out that many surprises are not Black Swans, but instead Gray Rhinos. Gray Rhinos are the big things coming at you that you should see, but that you miss simply because you are not looking. They are surprises, not because they are inherently nonlinear and unpredictable but because we are not paying attention to what is plainly before us. It is important to distinguish between true Black Swans versus Gray Rhinos because not every surprise is unpredictable, an issue not lost upon the US military.[1] Because Gray Rhinos are obvious, there should be data to indicate their presence, and because they are running directly at you, statistical modeling should be able to detect them. This report presents linear regression models that reveal the Gray Rhino drivers that lead to political instability and terrorism in the USCENTCOM AOR countries. While the research presented in this report is largely devoted to revealing Gray Rhinos, some Gray Rhino variables, such as famine and war, can sometimes arise very suddenly. Therefore, this research also provides insight into potentially lurking Black Swans.

Many assumptions had to be tested and theoretical and methodological issues addressed to arrive at the models presented in this report. A full description of that methodology is presented in Appendix A. The linear regression models presented in this report are supplemented with regression tree analyses that are designed to identify variables for which there are critical thresholds that can rapidly shift political systems from one state (stable or peaceful) into other states (unstable or violent). This provides a sense of the tipping points one may need to pay attention to and their critical levels that may indicate Black Swan events are more likely to happen. The main findings of the linear models for political stability and terrorism in the USCENTCOM AOR are presented first, then the regression tree analyses that identify critical thresholds in the USCENTCOM AOR. These findings provide USCENTCOM planners with indicators that they can monitor in order to detect looming Gray Rhino events, and the levels of those thresholds that might indicate when situations are becoming critical.

[1] https://madsciblog.tradoc.army.mil/51-black-swans-and-pink-flamingos/

# Political Stability in the USCENTCOM AOR—Gray Rhinos and Potential Black Swans

The World Bank political stability and non-violence scale, which varies from -2.5 (maximally unstable and violent) to 2.5 (maximally stable and non-violent) was used as a measure of political stability. Four different models were tested because per capita GDP, infant mortality, climate change impacts, and hunger were highly intercorrelated, confounding one another's effects. The hunger model provided the best fit to the USCENTCOM AOR data and included the most variables with a statistically significant relationship to political stability. When the statistical models were applied to the USCENTCOM AOR countries, most variables demonstrated the same relationships to political stability seen in the research literature (Braithwaite, Dasandi, & Hudson, 2019; Collier & Hoeffler, 1998; Fearon & Laitin, 2003) and in prior SMA studies (Kuznar, 2019b; Kuznar, Kuznar, & Aviles, 2019b), although there were several notable differences.

*Table 1. Summary of Political Stability Statistical Models for USCENTCOM AOR Countries*

| Model | Per capita GDP Model | Infant Mortality Model | Climate Change model | Hunger Model |
|---|---|---|---|---|
| Adjusted $R^2$ | 0.378 | 0.379 | 0.378 | 0.384 |
| Ln per capita GDP | -.040<br>(.087) | | | |
| Ln Infant Mortality | | 0.076<br>(0.086) | | |
| GAIN.Exposure | | | -0.755<br>(1.378) | |
| Ln Food Deficit | | | | -0.091**<br>(0.040) |
| Gain_Water_Vulnerability | -3.185**<br>(1.346) | -3.496**<br>(1.346) | -3.211**<br>(1.346) | -2.634**<br>(1.315) |
| Ln Elevation | -.565<br>(1.076) | -.548<br>(1.076) | -.556<br>(1.076) | -.726<br>(1.074) |
| LnPopulation | -0.789***<br>(0.081) | -0.724***<br>(0.117) | -0.804***<br>(0.077) | -0.863***<br>(0.081) |
| Youth Bulge | -.0.009<br>(0.006) | -.0.008<br>(0.006) | -.0.009<br>(0.006) | -.0.006<br>(0.006) |
| Ln Ethnolinguistic Fractionalization squared | -4.010<br>(10.280) | -4.111<br>(10.280) | -3.957<br>(10.280) | -3.873<br>(10.230) |
| Fuel Exports | 0.002<br>(0.001) | 0.002<br>(0.001) | 0.002<br>(0.001) | 0.002<br>(0.001) |
| Control of Corruption | 0.609***<br>(0.054) | 0.607***<br>(0.053) | 0.609***<br>(0.054) | 0.608***<br>(0.052) |
| Polity 2 Score squared | -0.002*<br>(0.001) | -0.002*<br>(0.001) | -0.002*<br>(0.001) | -0.002*<br>(0.001) |
| Risk Sensitivity of Poor | 0.017<br>(0.013) | 0.018<br>(0.013) | 0.016<br>(0.013) | 0.017<br>(0.013) |
| Middle Class Risk Sensitivity | -0.007<br>(0.039) | -0.007<br>(0.038) | -0.008<br>(0.038) | -0.009<br>(0.038) |
| Elite Wealth Sensitivity | -0.023**<br>(0.010) | -0.023**<br>(0.010) | -0.022**<br>(0.010) | -0.022**<br>(0.010) |

Youth bulges (high percent of population between 15 and 24 years of age), infant mortality, and per capita GDP were surprisingly unrelated to political stability in the USCENTCOM AOR, in contrast to global patterns described in the literature (Basedau, Fox, Pierskalla, Struver, & Vullers, 2017; Braithwaite et al., 2019; Carment, Samy, & Prest, 2008; Collier & Hoeffler, 1998; De Soysa & Neumayer, 2013; Elbawadi & Sambanis, 2002; Fearon, 2005; Fearon & Laitin, 2003; Goldstone et al., 2005; Shaver, Carter, & Shawa, 2019) and previous SMA studies (Kuznar, 2019b; Kuznar et al., 2019b). The effect of fuel exports also was not related to political instability, contrary to findings in the literature (Basedau et al., 2017; Braithwaite et al., 2019; Collier & Hoeffler, 1998; De Soysa & Neumayer, 2013; Elbawadi & Sambanis, 2002; Fearon, 2005). Furthermore, the effect of polity type (autocracy, weak democracy, mature democracy) was weak and opposite expectations compared to global samples (Iqbal & Starr, 2007, 2008; Kuznar, 2019b; Kuznar et al., 2019b). Globally, autocratic regimes and mature democracies tend to be the most stable polities. However, autocracies tended to be less stable in the USCENTCOM AOR.

Corruption and hunger (represented by the U.N. food deficit metric) were the variables most strongly related to political instability in the USCENTCOM AOR models, paralleling our global findings (Kuznar et al., 2019b). The vulnerability of water supplies to climate change was introduced to these models and was consistently related to political instability; insecurity in the presence of and access to the most fundamental thing we need, water, can destabilize a society.

The risk sensitivity of elites was related to political stability in the USCENTCOM AOR, consistent with earlier SMA research (Kuznar et al., 2019b). Risk sensitivity was assessed by examining relative wealth differences throughout each country. When relative wealth differences between wealthy people were extreme, they are predicted to become highly competitive with one another and more willing to risk opposing or competing in a political system that frustrates their aspirations (Kuznar, 2007). Consistent with the literature, risk acceptant elites are associated with political instability in the USCENTCOM AOR. The inequality-based risk sensitivity of middle class and poor segments in USCENTCOM AOR countries was not related to political stability, similar to earlier findings on a global scale (Kuznar et al., 2019b).

## Discussion—Political Instability Gray Rhinos in the USCENTCOM AOR

The strong association of hunger (measured as food deficit), water vulnerability, and corruption with political instability indicates that these are Gray Rhino indicators to watch. However, food deficit and water vulnerability also can come on quickly and unexpectedly in the case of droughts and famines. Therefore, these Gray Rhinos could be lurking Black Swans in the USCENTCOM AOR.

The fact that fuel exports were unrelated to political instability was surprising given the evidence for the so called “oil curse” in the literature and in our previous research on a global sample (Kuznar et al., 2019b). However, since this study focused only on USCENTCOM AOR countries, a number of whom are major oil and gas exporters, it is possible that there was insufficient variability in the fuel export variable to allow a correlation with the dependent variable of political instability.

The strong association of elite risk acceptance with instability is potentially the most important finding in terms of correcting common assumptions and focusing USG efforts to promote stability in the region. The consistency of this finding calls into question the common assumption that poverty is an underlying cause of political instability. To the contrary, it is dissatisfied wealthy people who pose a real danger to the state, not dissatisfied

masses. This is probably because genuine threats to state power require means and political skills possessed by wealthier members of society. Those discontented elites then tend to mobilize people from poorer segments of society as in a revolution, or simply challenge state power themselves as in a coup (Kuznar & Frederick, 2003). Grievances over inequality, poverty, and hunger compound political stability by making it easier for elites to mobilize the masses to challenge state power.

Wealth distributions generally change slowly and, therefore, their effects are most likely to behave like Gray Rhinos. However, economic crises that threaten elite wealth might bring on sudden and dramatic challenges to state power and, therefore, behave more like Black Swans in the USCENTCOM AOR. For instance, there is some evidence that US sanctions on Iran are fueling just this kind of discontent among wealthy and elite Iranians (Kuznar, 2019a).

# Terrorism in the USCENTCOM AOR—Gray Rhinos and Potential Black Swans

The Global Terrorism Index (GTI) was used as our measure of non-state actor generated terrorism (Institute for Economics and Peace, 2018); the GTI varies from 0 (no terrorism) to 10 (extreme amounts of terrorism). Three different models were run because per capita GDP, years of education, and corruption were highly intercorrelated and their effects confounded one another. The model that included the control of corruption variable provided the overall best fit to the data. When the terrorism model was applied to the USCENTCOM AOR, its independent variables generally had the same effects as seen in global studies (Boutton, 2019; Coggins, 2015; Younas & Sandler, 2017) and prior SMA models (Kuznar, 2019b; Kuznar, Kuznar, & Aviles, 2019a; Kuznar et al., 2019b).

Political terror, which refers to state physical repression, has the strongest association with terrorism, consistent with recent findings (Younas & Sandler, 2017). The negative sign and high statistical significance of the coefficient for control of corruption indicates that corruption in the USCENTCOM AOR is highly associated with terrorism. The positive sign of the coefficient for the polity 2 score indicates that democracy is associated with terrorism, a finding consistent with previous studies (Boutton, 2019). Large population size is also associated with terrorism, reflecting other studies (Boutton, 2019; Coggins, 2015). Youth bulge was not present in statistical models of terrorism in the literature but showed a highly statistically significant relationship to terrorism in the Central region countries in our model. Unemployment was also highly associated with terrorism in the USCENTCOM AOR countries. Fuel exports had a weak association with terrorism in the USCENTCOM AOR. While other research has previously found no association between IDPs and terrorism (Plummer, 2012), this study provided mixed results; IDPs were fairly strongly associated with terrorism, but not when the effects of corruption were controlled. Finally, the effects of war, measured as per capita battle deaths in a country, were highly associated with terrorism in the USCENTCOM AOR.

*Table 2. Summary Results of Terrorism Statistical Model on USCENTCOM AOR Countries*

| Model | Per capita GDP Model | Education Model | Corruption Model |
|---|---|---|---|
| Adjusted $R^2$ | 0.486 | 0.486 | 0.506 |
| Ln per capita GDP | 0.438*<br>(0.256) | | |
| Years Education | | 0.089<br>(0.056) | |
| Control of Corruption | | | -0.704***<br>(0.144) |
| Ln Population | 1.925***<br>(0.286) | 1.800***<br>(0.328) | 1.757***<br>(0.270) |
| Youth Bulge | 0.049***<br>(0.017) | 0.051***<br>(0.017) | 0.045***<br>(0.016) |
| Ln ELF Squared | -31.130<br>(27.450) | -30.860<br>(27.460) | -31.640<br>(26.910) |
| Religious Fractionalization | -29.640*<br>(17.820) | -26.120<br>(17.950) | -27.170<br>(17.470) |
| Per capita IDPs | 6.712**<br>(0.586) | 6.737**<br>(3.128) | 4.641<br>(2.997) |
| PerCap_Battle_deaths | 1,115.000***<br>(230.800) | 1,109.000***<br>(230.700) | 997.200***<br>(222.800) |
| Unemployment | 0.160***<br>(0.037) | 0.142***<br>(0.034) | 0.134***<br>(0.032) |
| Fuel Exports | 0.007*<br>(0.004) | 0.009*<br>(0.004) | 0.006*<br>(0.004) |
| Polity2 Score | 0.058***<br>(0.020) | 0.059***<br>(0.020) | 0.065***<br>(0.020) |
| Polity2 Score squared | 0.003<br>(0.004) | 0.003<br>(0.004) | 0.003<br>(0.004) |
| Political Terror Scale (PTS_S) | 1.060***<br>(0.096) | 1.061***<br>(0.096) | 1.048***<br>(0.094) |
| Risk Sensitivity of Poor | -0.035<br>(0.034) | -0.036<br>(0.034) | -0.035<br>(0.033) |
| Middle Class Risk Sensitivity | 0.067<br>(0.102) | 0.066<br>(0.102) | 0.050<br>(0.100) |
| Elite Wealth Sensitivity | 0.027<br>(0.028) | 0.025<br>(0.028) | 0.026<br>(0.027) |

## Discussion—Terrorism Gray Rhinos in the USCENTCOM AOR

Political variables seem to have the most impact on terrorism in the USCENTCOM AOR. The effect of state terror has recently been recognized as highly associated with non-state terrorism (Younas & Sandler, 2017), and our model reinforces this pattern in the USCENTCOM AOR. There appears to be a special effect of violating persons, not just rights, that may encourage extreme responses such as terrorism. Similarly, there appears to be an association between state corruption and terrorism in the USCENTCOM AOR, a complaint that terrorists often use to justify their movements (Halverson, Goodall Jr., & Corman, 2011; Pelletier, Lundmark, Gardner, Ligon, & Kilinc, 2016). The association between democracy and terrorism is often noted (Boutton, 2019; Kuznar et al., 2019b), and reproduced in this study. However, it is also notable that the democracies that exist in the

USCENTCOM AOR tend to be weak democracies at best, and so the real causal link may be the inability of a weak democracy to conduct effective counterterrorism operations.

Demographic and economic variables are also related to terrorism in the USCENTCOM AOR. Larger countries have more terrorism, a finding consistent with the literature (Boutton, 2019; Coggins, 2015). This may be due to the simple reason that very few people will resort to terrorism or the intentional killing of innocents to instill fear, and a larger population will statistically contain more people willing to go to such extremes. A large youth bulge is associated with terrorism in the USCENTCOM AOR, which may correspond to the success of terrorist organizations like ISIS in recruiting youth (Neer & O'Toole, 2014). The strong association between unemployment and terrorism in the USCENTCOM AOR indicates that a country's ability to provide its people a livelihood may be an important buffer against terrorism in the region. Productive work provides "significance" and is especially valued in the Islamic tradition (Faizal, Ridhwan, & Kalsom, 2013), and the lack of it has the potential to evoke even more outrage than it does in non-Islamic societies.

The refugee crisis, which has spilled into Europe, has created concerns that war and displacement may increase the possibility of terrorism. Focusing solely on the USCENTCOM AOR countries, there is an association between war deaths and terrorism. When corruption is controlled for by inclusion in the model, IDPs are not related to terrorism in the region. Therefore, the effects of war and the social dislocation it causes appear to present much more of a threat of terrorism than the presence of IDPs within the USCENTCOM AOR.

Most of these variables would be slow to change and, therefore, probably act more like Gray Rhinos. However, IDPs and battle deaths are the products of wars, which are infrequent and generally have abrupt and sometimes unexpected onsets. These variables may behave more like Black Swans. Unemployment might spike in relation to an economic crisis and begin to act more like a Black Swan than a Gray Rhino in that case. Finally, state repression has the potential to erupt suddenly in the case of state overreactions and quick crackdowns and might behave more like a Black Swan in those situations.

# Black Swan Tipping Points—Thresholds and Interactions in the USCENTCOM AOR

Linear models are useful for identifying Gray Rhino drivers and may lend insight into potential Black Swans under certain conditions, such as the famine and economic crisis suggestions mentioned in the sections above. However, phenomena are not always impacted by linear trends. Sometimes, an increase or decrease in an effect has minimal impact until a threshold is crossed. For example, a fever of one- or two-degrees Fahrenheit may cause minor discomfort but really poses no threat to an individual's physiology. However, once a threshold of 104°F (40°C) is reached, body functions become overwhelmed and the individual is in danger of dying. Regression trees are machine learning methods that identify thresholds in critical variables (Rokach & Maimon, 2015), and they were applied to the USCENTCOM AOR country data to explore critical thresholds that could represent tipping points for political instability or terrorism. Regression trees use recursive binary partitioning that splits data into sets based on threshold values that reduce the mean square deviance in predicting outcome variables (Rokach & Maimon, 2015). The process iterates within each partition, identifying the variables and their thresholds that explain the most variance at each partition. The regression tree algorithm does not allow for fixed effects modeling, and therefore the effects of country and year could not be controlled. This may explain why some variables, such as elevation, appear to have significant effects in these models when they do not in

the linear models presented above. However, this method produced largely similar results to the panel regressions with added insights regarding interactions and thresholds.

## Political Stability in the USCENTCOM AOR: Thresholds and Interactions

The result of the regression trees for the political stability scale are presented in Figure 2. The results reinforce the importance of corruption as a cause of instability. The greatest levels of instability (measured as a negative political stability score) are in countries with:

- Very rugged terrain (greater than 3408 m, approx. 11,000 feet, maximum elevation difference), and very low control of corruption.
- Very rugged terrain, better control of corruption, but a large youth bulge (>39.5%) and a large population (>161,500,000).
- Countries with less rugged terrain, but low control of corruption, water insecurity, and weak democracy.

The most stable countries were in situations with not very rugged terrain and high control of corruption.

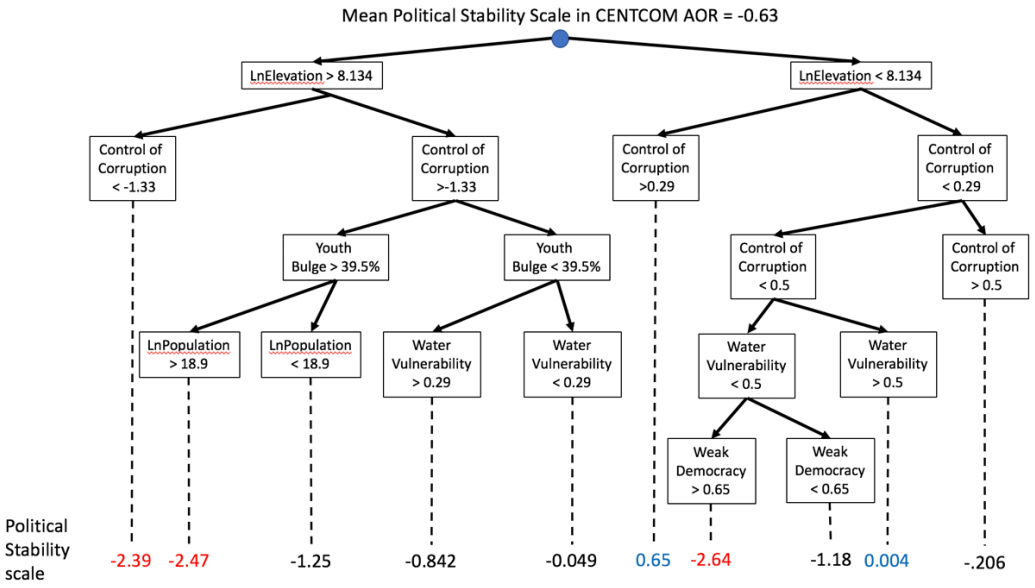


*Figure 1. Regression Tree for Political Stability in the USCENTCOM AOR*

Control of corruption emerged in this analysis as the variable that most impacted political stability. Wherever it is low and, therefore, corruption is especially high, political instability arises. Reinforcing the critical role of corruption in destabilizing countries, in situations where water vulnerability is low, corruption interacts with weak democracy to create political instability. Finally, the most stable societies were ones that did not have excessive elevation differences and had strong control of corruption, reinforcing the importance of controlling corruption for stabilizing society.

The significance of the youth bulge threshold is consistent with some statistical studies of political instability (Fluckiger & Ludwig, 2018; Yair & Miodownik, 2016), but may not be relevant in current times. In 2018, the countries with the largest youth bulges had only 25% of the population between 15 and 24 years of age. Youth

bulges have decreased historically, so this finding is theoretically relevant, but largely an artifact of the long history of observations in our data.

The fact that terrain emerged as a critical variable is consistent with other statistical models of political instability (De Soysa & Neumayer, 2013; Fearon, 2005; Fearon & Laitin, 2003; Shaver et al., 2019). The received wisdom is that mountainous regions are difficult to administer and foster social divisions along the lines of terrain, making governance difficult. The tipping point threshold identified in the USCENTCOM AOR is extremely high for most countries globally; a country would have to have a maximum elevation difference of 3408 meters, or over 11,000 feet, in order to be so mountainous that it would be difficult to govern. However, eight of the 20 countries in the USCENTCOM AOR meet that criterion, including Iran, Iraq, Yemen, Afghanistan, Pakistan, Kazakhstan, Tajikistan, and Uzbekistan.

## Terrorism in the USCENTCOM AOR: Interactions and Thresholds

The result of the regression trees for the global terrorism index are presented in Figure 3. The results reinforce the importance of state terrorism as a cause of instability. The greatest levels of terrorism are in countries where state political terror is very high and population is large (threshold above 161,200,000). Countries that experience the lowest levels of terrorism in the USCENTCOM AOR are those with low polity 2 scores (highly autocratic societies), even when battle deaths are high.

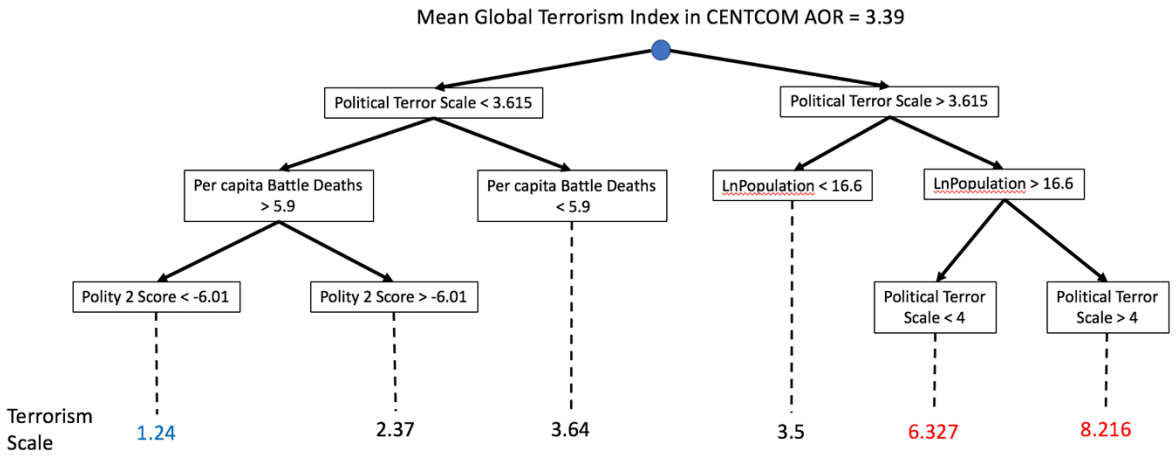


*Figure 2. Regression Tree for Terrorism in the USCENTCOM AOR*

# Implications

These research findings have implications for potential actions the USG, or USCENTCOM as an agent of the USG, may consider promoting political stability or counterterrorism. This section explores those possibilities.

## Implications for Political Instability

Because the food deficit is so strongly related to political instability, monitoring food availability and food prices may provide advance I&W of looming Gray Rhinos, or in the case of market volatility, spikes in food prices could bring on instability in a Black Swan fashion.

Water availability is a clearly a looming Gray Rhino. Much of the population of the USCENTCOM AOR is dependent on groundwater trapped in fossil aquifers (Gleick, 2014; Voss et al., 2013), which can only receive minimal replenishment from precipitation; basically, water is a finite and dwindling resource in the region. The source of surface water in the region is dangerously concentrated in the hands of a few countries, who can and at times have used their water politically against other countries, destabilizing the region. In the Middle East, Turkey can control much of the surface water runoff to Syria and Iraq (Voss et al., 2013), and Kyrgyzstan and Tajikistan have similar control in Central Asia.

Water availability and food deficits have a history of interaction in the region. Drought in Syria drove rural farmers to urban centers, while at the same time droughts in China and Russia decreased crop yields, raising food prices in the Middle East (Johnstone & Mazo, 2013). The resulting social tensions have been related to the beginnings of the Arab Spring in Syria (Gleick, 2014; Johnstone & Mazo, 2013). Keeping an eye on these emerging Gray Rhinos and especially when they randomly spike like Black Swans can provide improved I&W of instability.

The USG cannot readily change dwindling water supplies, droughts, and global food prices, but political variables can be impacted by USG policy and USCENTCOM could potentially be an agent of that impact. The most pervasively influential variable that impacts political stability in the USCENTCOM AOR is political corruption. The results of the linear models and the regression tree threshold analyses emphasize that corruption undermines political stability and its control promotes political stability. Corruption can be very difficult to root out and takes time, and therefore behaves more like a Gray Rhino. However, it is a variable the USG and DoD monitors in countries and can influence with DIMEFIL (Diplomatic, Informational, Military, Economic, Financial, Intelligence, Legal) levers such as sanctions and the withholding of aid.

## Implications for Terrorism

Political variables were most related to terrorism in the USCENTCOM AOR, especially state terror as measured by the US Department of State political terror scale (PTS). States can oppress their populations in many ways (denying freedom of assembly, the press, voting), but the aspect of state repression that appears to be most associated with terrorism is physical violation of the individual (Younas & Sandler, 2017). State terror was the most significant factor associated with terrorism in the USCENTCOM AOR in all models; when states violate the physicality of the person, it appears to elicit extreme responses. Generally, the culture of state terror would be hard and slow to change and therefore would behave more like a Gray Rhino, except in cases where states overreact and institute major crackdowns and pogroms, in which case they could theoretically tip a system into terrorism abruptly. USG sanctions against state terror have the potential to buffer against terrorism.

Both the linear models and the threshold models emphasize the fact that highly autocratic regimes can tamp down terrorism because of their ability and willingness to control their populations. There are no mature democracies in the USCENTCOM AOR and the positive association of democracy and terrorism in the region indicates that democratization in the region, which is only ever partial, makes terrorism more likely in the region. The USG can influence the political systems of the region. An ultimate goal would be stable, mature democracies, which ultimately would most effectively limit terrorism. However, the dilemma exists that the pathway to mature democracy necessitates journeying through weak democracies, which actually increase the likelihood of terrorism.

The results of our modeling highlight a further consideration concerning state terror, repression, and polity type. Autocratic regimes, if they incorporate state terror in their suite of control mechanisms, could be simultaneously controlling terrorism in their own country but creating terrorists who can become problems for other countries. Saudi Arabia could be an exemplar; it has the lowest possible polity 2 score (-10) indicating a highly autocratic regime and is high on the DoS political terror scale (3 of 5).

Corruption was highly associated with terrorism in the USCENTCOM AOR and as stated for political stability, is a variable that the USG has ways to influence.

The combination of a youth bulge and high unemployment appears to be a volatile mix that can increase terrorism in the USCENTCOM AOR. The USG cannot alter demographic trends, but it may be able to influence economic variables such as unemployment and potentially buffer against increased terrorism. Youth bulges change slowly and behave like Gray Rhinos, and generally unemployment behaves similarly, although economic crises that spike unemployment could take on a Black Swan character and lead to sudden spikes in terrorism according to these models.

Finally, the outbreak of major wars, which the USG has some potential to influence through diplomacy, can impact terrorism levels according to these models. The less outright war that exists in a region, the less terrorism should be generated in that region. Wars tend to behave like Black Swans (Bellomo et al., 2013), and therefore USG counterterrorism efforts might best plan for random and rare spikes in terrorism associated with war in the USCENTCOM AOR.

# Appendix A: How to Hunt Gray Rhinos with Linear Modeling of Political Stability and Terrorism

Linear models based on regularly gathered and available data provide a means of monitoring one's environment, identifying the drivers of Gray Rhinos, and anticipating their effects. The starting point of this analysis was to canvass the literature on statistical modeling of political stability and terrorism and compile extensive lists of independent variables. Fifty-one independent variables were identified in models reviewed in 73 peer-reviewed publications on political stability and 22 peer-reviewed publications on terrorism (Table 3). A number of statistical issues plague country-level analyses, including non-normality, endogeneity, multicollinearity, dubious causal connections, and explanatory failure between independent and dependent variables.

*Table 3. Independent Variables List*

| Variable | Variable Type | Variable | Variable Type |
|---|---|---|---|
| Ethnolinguistic fractionalization | Demographic | Education | Economic |
| Religious fractionalization | Demographic | Education Gini | Economic |
| Percent Muslim | Demographic | Remittances | Geographic |
| Human Development Index | Demographic | Africa | Geographic |
| Infant mortality | Demographic | Mountains | Geographic |
| Population | Demographic | Climate Change | Geographic |
| Pop Density | Demographic | Precipitation | Geographic |
| Pop Growth | Demographic | Temperature | Geographic |
| Youth Bulge | Demographic | Bad Neighbors | Political |
| Sex Ratio | Demographic | CPI | Political |
| IDPs/Refugees | Demographic | External Intervention | Political |
| Food Insecurity | Demographic | Instability | Political |
| Internet/Mobile Phone/Media | Demographic | Governance confidence | Political |
| Economic Openness | Economic | Polity Score | Political |
| GDP | Economic | Polity Score squared | Political |
| GDP growth | Economic | Personal Security | Political |
| Per capita GDP | Economic | State Discrimination | Political |
| Oil | Economic | War | Political |
| Secondary Diamonds | Economic | Governance | Political |
| Natural Resources | Economic | Rule of Law | Political |
| Foreign Direct Investment, Official Direct Aid | Economic | Years Independent | Political |
| Inflation | Economic | Peace Years | Political |
| Uneven Development | Economic | Cold War | Political |
| Unemployment | Economic | lagged DV | |
| Social Mobility | Economic | Colonialism | Political |

**Non-normality**. Classical statistical models assume that variables are normally distributed. The central limit theorem demonstrates that large enough sample size can overcome violations of normality. However, it is best if one's variables are as normally distributed as possible. A number of variables were heavily skewed and non-normal. In all of these cases, taking the natural log of these variables made their distributions more normal.

**Endogeneity** is a situation where the dependent variable one wants to explain is actually partially composed of the independent variables one is using. This is especially the case when a dependent variable is a scale made up of a composite of different factors. For instance, the Fragile States Index compiled by the Fund for Peace (Messner & Haken, 2017) weighs information on security, elite competition, group grievances, economic decline, uneven development, brain drain, emigration, state legitimacy, public services, human rights, rule of law, demography, refugees, and foreign interference. This scale provides a useful composite measure of a state's stability, but it is made of many of the variables that one would model to explain its stability. It therefore would be an inappropriate choice of dependent variable. Two of the independent variables were eliminated because of endogeneity. The U.N. Human Development Index is a composite measure based on per capita GDP, infant mortality, and education, containing some independent variables whose influence we wanted to measure directly. Some models in the literature lag their dependent variable in an effort to control for the inertial effects of time. However, this incorporates the very variable one wishes to explain in the model itself. Time effects were controlled in our models by using fixed effects regression on year (see below).

**Multicollinearity** describes high intercorrelation between independent variables. This is a problem because if two variables are highly correlated, it is extremely difficult to determine which variable has a causal effect on the dependent variable. Especially high correlates existed between infant mortality, per capita GDP, education, corruption, food insecurity, and governance. If any of these variables were used, they were used in separate models to avoid their confounding effects.

**Failed Explanatory Value**. We identified 51 independent variables in the literature, but not all demonstrated a relationship to the dependent variables, especially once they were controlled for by other variables. Also, not all variables were considered worthy of consideration by many researchers. In order to focus our analyses on the most promising and relevant variables, of the independent variables that remained from the above described selection process, we selected those that for each dependent variable were used more than average and were statistically significantly related to the dependent variable more often than average.

In addition to variables drawn from the literature, a measure of risk sensitivity was introduced based on the wealth distribution of a population. In previous research, this measure has correlated with political risk taking, including coups, revolutions, and terrorism (Kuznar, 2002, 2007, 2019b; Kuznar & Frederick, 2003; Kuznar et al., 2019b). The measure is based on the relative advantages or disadvantages of taking a risk to increase one's social status. For this project, the measure was modified to take into consideration the widespread phenomenon of loss aversion in which an individual who is normally averse to taking risk takes risk to avoid a loss (Kahneman & Tversky, 2000; Tversky & Kahneman, 1992, 2000). The theoretical basis and full methodological explanation can be found in these sources (Kuznar, 2007; Kuznar et al., 2019b).

The remaining independent variables were used in successive models, revealing further issues with collinearity and with failure to explain variance. Variables were eliminated based on these issues until a final set of variables was retained based on explanatory value or a variable's relevance to a theoretical proposition or policy. For

instance, some variables that were not statistically significantly related to the dependent variable were retained to demonstrate their non-relevance. The final sets of variables used in the models are found in Tables 4 and 5 .

*Table 4. Final Set of Independent Variables for Political Stability Models*

| Political Stability Model Variable | Definition |
|---|---|
| Ln per capita GDP | Self-explanatory |
| Ln Infant Mortality | Self-explanatory |
| Climate Change | The GAIN.Exposure scale from the Notre Dame University Global Adaptiveness Initiative measures exposure to climate change effects in general. |
| Ln Food Deficit | The U.N. defines food deficit as the deficit of calories experienced by a country's under-nourished population. |
| Gain_Water_Vuln | The GAIN.Water vulnerability scale from the Notre Dame University Global Adaptiveness Initiative measures water insecurity. |
| Ln Elevation | Elevation refers to the maximum elevation distance in a country and is used as a measure of terrain ruggedness. |
| Ln Population | Population size |
| Youth Bulge | The proportion of the population between 15 and 24 years of age. |
| Ln Ethnolinguistic Fractionalization | Ethnolinguistic fractionalization measures the probability that two randomly chosen people belong to different ethnic or linguistic groups in a country |
| Fuel Exports | Fuel exports as percentage of merchandise exports |
| Control of Corruption | The World Bank Control of Corruption scale varies from -2.5 (maximal corruption) to 2.5 (complete control of corruption) |
| Polity2 Score2 squared | The Polity 2 score from the Polity IV database measures a country's level of autocracy (-10 maximum) to democracy (10 maximum). Its square measures the extent to which a country is either very autocratic or democratic. |
| GrowthLoAP Risk Sensitivity of the Poor | This is a measure of the poorest segment of society's acceptance of taking risks as a function of inequality. |
| GrowthPosAP Middle Class Risk Sensitivity | This is a measure of middle-class aversion to risk as a function of inequality. |
| GrowthHiAP Elite Risk Sensitivity | This is a measure of elite acceptance of taking risk as a function of inequality. |

*Table 5. Final Set of Independent Variables Used in Terrorism Models*

| Terrorism Model Variable | Definition |
|---|---|
| Ln per capita GDP | Self-explanatory |
| Years Education | Years education is measured by World Bank estimated school lifespan |
| Control of Corruption | The World Bank Control of Corruption scale varies from -2.5 (maximal corruption) to 2.5 (complete control of corruption) |
| Ln Population | Population size |
| Youth Bulge | The proportion of the population between 15 and 24 years of age. |
| Ln Ethnolinguistic Fractionalization | Ethnolinguistic fractionalization measures the probability that two randomly chosen people belong to different ethnic or linguistic groups in a country |

| | |
|---|---|
| Religious Fractionalization | Religious fractionalization measures the probability that two randomly chosen people belong to different religious groups in a country |
| Per capita IDP | The impact of IDPs (Internally Displaced Persons) on a country is measured by number of IDPs divided by the country population |
| PerCap_Battle_deaths | The impact of war on a population is measured by the battle deaths experienced by the population divided by its over all population. |
| Unemployment | Unemployment is measured by the World Bank estimate of percent unemployment of the working age population. |
| Fuel Exports | Fuel exports as percentage of merchandise exports |
| Polity2 Score2 squared | The Polity 2 score from the Polity IV database measures a country's level of autocracy (-10 maximum) to democracy (10 maximum) |
| Polity2 Score2 squared | The Polity 2 score from the Polity IV database measures a country's level of autocracy (-10 maximum) to democracy (10 maximum). Its square measures the extent to which a country is either very autocratic or democratic. |
| Political Terror Score (PTS_S) | The political terror score is US Department of State measure of the extent to which a country's government uses state terror against its population. |
| GrowthLoAP Risk Sensitivity of the Poor | This is a measure of the poorest segment of society's acceptance of taking risks as a function of inequality. |
| GrowthPosAP Middle Class Risk Sensitivity | This is a measure of middle-class aversion to risk as a function of inequality. |
| GrowthHiAP Elite Risk Sensitivity | This is a measure of elite acceptance of taking risk as a function of inequality. |

The dataset was comprehensive but had substantial missing data, and data gaps increased as one went back in time. In keeping with standard practices (Choi, Luo, Pattipati, Qiao, & Chigusa, 2006; Fearon, 2005; Safer-Lichtenstein, LaFree, & Loughran, 2017), data were imputed in order to fill those gaps with reasonable interpolations. A number of imputation methods are available. A machine learning technique, random forests, was used. Random forest imputation creates regression functions from the existing data of all the variables in the dataset to interpolate the missing data. Random subsets of data are chosen and the predictions from each "tree" are averaged together to produce robust estimates of missing data. It is a nonparametric imputation method that copes with mixed-type variables, nonlinear relations, complex interactions, and high dimensionality while making minimal assumptions about the distribution of the data (Cutler, Cutler, & Stevens, 2012; Toukan, 2019).

Stepwise regression was used to prune the list of independent variables further. Stepwise regression adds variables that increase the explanatory power of a model significantly and eliminate those that fail to increase a model's explanatory power (Cohen & Cohen, 1975). Independent variables eliminated by the stepwise procedures were eliminated from further consideration in this study. Because the data on each country spans the period from 1960 to 2019, it is necessary to control for the inertial effect of time, and most researchers maintain that countries are so unique that unobserved variables unique to each country also impact results (Basedau et al., 2017; Bjorvatn & Farzenegan, 2015; Boutton, 2019; Hegre, Oneal, & Rusett, 2010; Neumayer & Plumper, 2010; Phillips, 2015; Shaver et al., 2019; Wood & Sullivan, 2015). Therefore, analyses were conducted using fixed effects, or panel, regressions (D. Bates, Machler, Bolker, & Walker, 2015; Nwakuya & Ijomah, 2017; Wooldridge, 2010) that account for the effects of country and time. The models were trained on a global sample of all countries, and then specifically applied to the USCENTCOM AOR countries.

# Appendix B: Statistical Models of Political Stability and Terrorism

This appendix contains the references for all statistical models reviewed in the literature.

## Political Stability Models

Seventy-three publications that contained statistical models of political stability were reviewed in order to catalogue the independent variables scholars have proposed and empirically tested for their impact on political stability. They are, alphabetically as follows (Asal, Findley, Piazza, & Walsh, 2016; Bartusevičius, 2014, 2017; Basedau et al., 2017; R. H. Bates, 2008; Bell, Cingranelli, Murdie, & Caglayan, 2013; Bergholt & Lujala, 2012; Bjorvatn & Farzenegan, 2015; Böhmelt, Bove, & Gleditsch, 2018; Bohnet, Cottier, & Hug, 2016; Bormann, Cederman, & Vogt, 2016; Braithwaite et al., 2019; Breslawski & Ives, 2018; Buhaug, 2010; Carment et al., 2008; Chaudoin, Peskowitz, & Stanton, 2016; Chiba & Gleditsch, 2017; Colgan, 2015; Collier & Hoeffler, 1998; J. M. Conrad, Greene, Walsh, & Whitaker, 2018; de la Calle & Sánchez-Cuenca, 2012; De Soysa & Neumayer, 2013; DeMeritt & Young, 2013; DiGiuseppe, Barry, & Frank, 2012; Dreher & Kreibaum, 2016; Elbawadi & Sambanis, 2002; Fearon, 2005; Fearon & Laitin, 2003; Fluckiger & Ludwig, 2018; Gibler, 2011; Gibler & Miller, 2014; Girod, Stewart, & Walters, 2016; Goldstone, 2008; Gustafson, 2019; Han, O'Mahoney, & Paik, 2013; Hendrix & Haggard, 2015; Hendrix & Salehyan, 2012; Holtermann, 2012; Houle, 2016, 2019; Houle & Bodea, 2017; Hultquist, 2015; Hunziker & Cederman, 2017; Iqbal & Starr, 2007, 2008; Jazayeri, 2016; Jones, Mattiacci, & Braumoeller, 2017; Karakaya, 2016; Klein & Tokdemir, 2016; Konaev & Brathwaite, 2017; Koren, 2019; Koren & Bagozzi, 2017; Koubi, Bernauer, Kalbhenn, & Spilker, 2012; Koubi & Böhmelt, 2013; Koubi, Spilker, Böhmelt, & Bernauer, 2013; Landis, 2014; Päivi Lujala, 2010; Paivi Lujala, Gleditsch, & Gilmore, 2005; Miljkovic & Rimal, 2008; Østby, 2016; Regan & Frank, 2014; Rieger, 2008; Roy, 2016; Rustad, Camilla, Buhaug, Falch, & Gates, 2011; Sekhar, 2010; Shaver, Carter, & Shawa, 2016; Slettebak, 2012; Smith, 2015; Thies, 2010; Toukan, 2019; Wegenast & Basedau, 2013; Yair & Miodownik, 2014).

## Terrorism Models

Twenty-two publications that contained statistical models of political stability were reviewed in order to catalogue the independent variables scholars have proposed and empirically tested for their impact on political stability. They are, alphabetically as follows (Boutton, 2019; Boyd, 2016; Brockhoff, Krieger, & Meierrieks, 2014; S.-W. Choi & Piazza, 2016; Coggins, 2015; J. Conrad & Milton, 2013; Enders, Hoover, & Sandler, 2016; Gelpi & Avdan, 2015; George, 2016; Ghatak, Gold, & Prins, 2017; Lee, 2016; McLean, Hinkkainen, De la Calle, & Bapat, 2016; Nemeth, Mauslein, & Stapley, 2014; Piazza, 2011, 2012; Plummer, 2012; Younas & Sandler, 2017).

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