How Does Climate Change Influence Regional Instability?*

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Abstract

Motivated to measure the stability of a country quantitatively and more accurately, our team built a mathematical framework to identify the status of the country. We categorize countries into three states: stable, vulnerable, and fragile state. We arrive at a composite index that considers different factors in the economy, politics, demographics and climate change in a country. Based on the logistic growth model, we create a dynamic system that not only describes the current state of a country but also predicts equilibrium states that the country would approach over time. We utilize a bifurcation plot to depict tipping points between three states for a country. We then apply our framework to Syria, Cuba and New Zealand. By calibrating parameters and comparing different factors in each country, we find that New Zealand is steadily reaching equilibrium but Syria and Cuba have been significantly impacted by negative climate changes. However, if it were not for the negative effects of climate change, Syria would approach a vulnerable state and Cuba a stable state.

Introduction

Despite scientific consensus about global warming, there is denial of climate change and the extent to which it is caused by humans. Climate change includes increased droughts, shrinking glaciers, temperature rise and sea level rise. These and other factors of climate change can affect the stability of a country in terms of the government providing basic essentials to the people.

We build a mathematical framework to determine a country's fragility, using a composite measure considering multiple factors, including economic, political and demographic indicators and climate change. We select three countries, Syria, Cuba and New Zealand, as case studies and further analyze the concept of "tipping points" in their specific contexts.

We examine the potential effects of human intervention. Finally, we discuss our limitations and strengths of our modeling, consider the scenarios for smaller and larger "states", and suggest future research.

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Assumptions

- Our framework measures the market impacts of different factors such as climate change, economic status, political stability and demographic profiles in the unit of US dollars because we think it is more efficient to quantify and examine the extent of effects.
- We define the state as a country for consistency and data collection purpose.
- We assume all data we obtain are trustworthy since all of sources are reliable. Thus, we are confident that our metrics can reflect the accurate condition.

Framework

Defining Fragility

Before devising our model, we first define three possible states of a country: stable state, vulnerable state, and fragile state.

- **Stable State.** A stable country should be less likely to be influenced by the incidents such as economic downturns, natural disasters, or political instability. Even if there is a crisis, a stable country can quickly recover and return to its equilibrium state.
- **Vulnerable state.** A vulnerable country is more susceptible than a stable country to the

changes in the economy, politics, demographics and climate. A damaging event could cause the country leave its current state and gradually become a fragile state; a favorable event could, on the contrary, lead the country to approach a stable state.

- **Fragile state.** A fragile country is the currently experiencing fluctuations in economy and politics. It does not possess a strong economy or a well-regulated society. As a result, any small turbulence could bring large impacts on all factors. Moreover, even if the country manages to recover from these disturbances, it can only resume to its previous fragile state.

The Model

To quantify a country's fragility, we use a dynamical system, in terms of "money value" (M), which we measure in monetary terms, to estimate the impacts of changes in different factors on a country. However, we believe that the economy is not the sole predictor of the fragility of a country. Thus, in our model, we incorporate M factors including economy E, politics P, demographics D and climate C. However, we measure those factors in monetary terms:

$$M = f(E, P, D, C) \tag{1}$$

We assume that the growth rate of M does not directly depend on time, that the derivative of M is an autonomous function. The growth rate of M constitutes positive impact $p(M)$ minus the negative impact $g(M)$.

$$\frac{dM}{dt} = p(M) - g(M) \tag{2}$$

The positive impact considers the natural growth of the market itself accompanied with a limited capacity which varies depending on the parameters. The negative impact is composed of human intervention, disturbances due to climate change, and other unfavorable variation in the parameters that we have defined.

Inspired by the outbreak system by Ludwig et al. (1978), we obtain the functional forms

$$p(M) = m_1 M(1 - \frac{M}{km_2}),\ g(M) = \frac{BM^2}{A^2 + M^2} \tag{3}$$

where

- $p(M)$ is the economic growth with limited capacity;
- m_1 is the natural growth rate;
- m_2 is the maximum of economy capacity;
- k is a scale factor that measures how economy, politics, demographics and climate change would affect the actual limit of the market. To come up with the value of k, we use a composite index consisting of metrics in economy, politics, demographics and climate change; and
- $g(M)$ represents the negative impact that could potentially slow down the market growth. In the early development stage, M is small, and there is little for the negative impact to affect, so the negative impact is not significant at first. However, when the market exceeds a critical level A, the negative impact would turn on quickly. This happens when harmful events have built up to an extent that they cause a chain of reactions, and the impact would finally reach its limitation B.

Therefore, we have the whole model:

$$\frac{dM}{dt} = m_1 M(1 - \frac{M}{km_2}) - \frac{BM^2}{A^2 + M^2} \tag{4}$$

To investigate the model more easily, we converted to a dimensionless function. We set $x = \frac{M}{A}$, $\tau = \frac{Bt}{A}$, $r = \frac{Am_1}{B}$, and $s = \frac{km_2}{A}$ arriving at

$$\frac{dx}{d\tau} = rx(1 - \frac{x}{s}) - \frac{x^2}{1 - x^2} \tag{5}$$

which has only two parameters, r and s.

Metrics for Assessing Fragility

Our metrics are similar to indicators used in the Fragile States Index (FSI). But, instead of rating those factors, we target to collect both quantitative and qualitative data by country and by year. Our metrics will be more concise because we find that there are some overlapping variables in FSI. For example, both Factionalized Elites of the Cohesion indicators and Uneven Development in Economic indicators have considered the wealth distribution and try to assess the equality of wealth (Marshall and Cole, 2017). In the end, using RStudio, we process all the datasets and obtain a composite index.

Climate Change

Any unexpected climate change is expected to have negative impacts on human societies and economies, which may bring huge economic losses.

- **Natural disasters.** EM-DAT contains data on the occurrence and effects of different types of natural disasters worldwide from 1900 to present. However, the data is not publicly available. So we use *probabilistic risk results* provided by UNISDR. The probabilistic risk results provide an estimate of possible loss levels in a country based on historic events. This data is useful because it considers damages caused by small, moderate and severe events and obtains a robust metric for risk ranking and comparison.
- **Deforestation.** Food and Agriculture Organization (FAO) contains comprehensive forestry datasets such as forest coverage, reforestation, burned forest and economic value of the country's forestry value. Among them, we select the annual *Tree cover loss* rate by country with unit of hectare to reflect the deforestation rate as a part of the climate change.
- **Droughts/floods.** We use *Precipitation Anomaly* from World Bank to reflect occurrence of both droughts and floods. This dataset includes historical monthly precipitation worldwide from 1900 to present.
- **Rising Sea Levels/Shrinking Glaciers.** Although sea level rise is a major component of the global climate change, it is not a typical question for all countries. Since rising sea level and green house effects are tightly related, we only consider temperature rises instead of rising sea level.
- **Rising temperatures.** We retrieve historical temperature data from World Bank. This data is called *Global Historical Climatology Network version 2*, with station monthly mean temperatures and station metadata created by U.S. National Climatic Data Center. This dataset contains quality-controlled, adjusted monthly mean temperatures.

Economic Metrics

Our economic metametric considers factors related to economic decline within a country. In addition to the economic factors listed below, we have also considered unequal development and other relevant factors including government debts/deficits, currency fluctuation, consumer confidence and foreign investment. More detailed descriptions of those variables are in the Appendix.

- **Real Gross National Product (GNP) per Capita.** *Real GNP* calculates the value of all final goods and services produced by the means of production owned by all domestic and overseas citizens of a country in a given period of time. It is different from the Gross Domestic Products (GDP) because GDP calculates the total values of products and services produced in the country. In other words, GNP measures the income of people within the country while GDP measures the economic productivity in a country (Stiglitz, 2009). Therefore, although GDP is more widely used, we think GNP works better in our model because we want to find a metric that can better represent the well-being of a country. So we obtain our data of annual GNP by country from Knoema over the period of 1998 through 2012.
- **Unemployment Rate.** Our group has used the *unemployment rate, % of total labor force* dataset retrieved from Organization for Economic Co-operation and Development (OECD) over the period of 1953-2017. We use unemployment rate as a metric to reflect the economic decline within a country and to estimate the stability of a country.
- **Inflation.** The *Inflation, consumer prices (annul %)* dataset is obtained from International Monetary Fund, International Financial Statistics and data files. This inflation rate measures the change in the prices of a basket of selected consumer goods and services. The year 2010 is the base year for the calculation of inflation rate in our dataset.
- **Poverty level.** *Poverty headcount ratio at $3.20 a day (2011 PPP) (% of population)* dataset is obtained from The World Bank. This dataset contains data in selected years from 1979 to 2016. An alternative dataset is *Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population)*, but we think $3.30 reflect a normal level of spending better than $1.90. It is difficult for one to live with only $1.90 a day even if one lives in a country with

a low price level, while $3.30 a day should prevent one from starving in most countries.

Political and Demographic Indicators

Our team collects data of corruption, health, education, water, energy and freedom of speech to represent the political indicator of the state. We use those variables to not only reflect the basic level and quality of state functions and services but also indicate the openness of a government and its relationship with citizens. We have also taken account of demographical factors including population density, natural resources abundance, internally displaced persons, and brain drain. We believe that those variables reflect the pressures upon the state deriving from the population itself and those pressures caused by the forced displacement of large communities. Details of variables and data we selected are in the appendix.

Equilibrium and Tipping Points

Not only do we want to analyze the impact of each parameter on the overall performance of a country, we are also interested in further studying the pattern of a country's state of fragility. Hence, we introduce two terms, *equilibrium* and *tipping point*. An equilibrium means a steady state of a country; it is indicated by a stationary point of M, that is, a point where $M' = 0$. A tipping point describes the watersheds between different equilibria; in our model, the occurrence of a tipping point suggests a change in steady states.

Equilibrium

Using the dimensionless form of the function, we set $\frac{dx}{d\tau} = 0$ equal to zero to find the stationary points.

$$\frac{dx}{d\tau} = 0, \qquad rx(1 - \frac{x}{s}) = \frac{x^2}{1 + x^2} \tag{6}$$

Equation 6 has a stationary point at $x^* = 0$. Intuitively, $x^* = 0$ is always an unstable stationary point, because when x is small, negative impacts too are small, so that the market value would grow exponentially away from 0. We can obtain other stationary points as solutions to

$$r(1 - \frac{x}{s}) = \frac{x}{1 + x^2}. \tag{7}$$

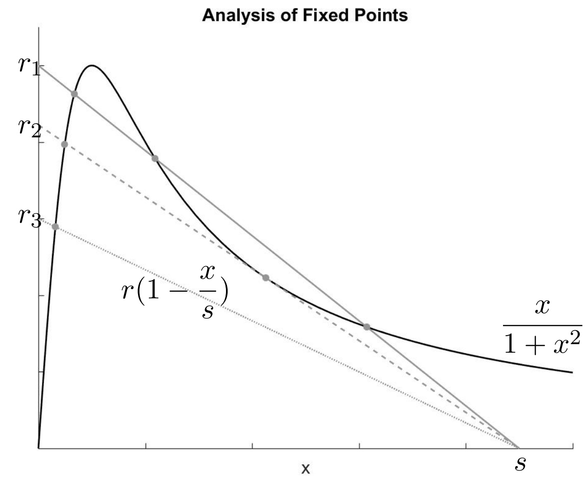

Figure 1: This figure shows the behavior of equilibria corresponding to different values of r and s. The black curve represents $\frac{x}{1+x^2}$ and the gray lines represents $r(1-\frac{x}{s})$ with different r values.

This equation expands to a cubic equation in x, which must have either one or three real solutions (which must be positive, according to Descartes' rule of signs). But it is easier to analyze the equation graphically, by finding the intersections of the two functions on each side of the equation. Since the right-hand side depend only on x, we can alter values of the parameters r, s on the left-hand side to see the changes in the stationary points.

In Figure 1, we see that for a fixed s, shifts in r return different behaviors of stationary points.

When $r = r_1$, the equation returns three roots, which means the function has three stationary points. However, when r decreases to r_2, the latter two stationary points collapse into one stationary point, where the line $r(1 - \frac{x}{s})$ intersects the curve $\frac{x}{1-x^2}$ tangentially. As r continues decreasing, there remains only one fixed point. A similar pattern can be observed as r-value increases from r_1. To determine the stability of the fixed points, we recall that $x^* = 0$ is an unstable point and the stability of fixed points must alternate as x increases.

Tipping Points

The phenomenon described above corresponds to two saddle-node bifurcations, where two stationary points coalesce into one and then disappear. For easier understanding, in Figure 2 we draw $M' = \frac{dM}{dt}$ vs. M, showing different solutions corresponding to different (r, s) values.

we find the connection between fragility states and the behaviors of different types of $\frac{dM}{dt}$ curves.

- **One stationary point, near 0.** When a curve has staionary point near zero, like the lowermost curve in Figure 2, M will always approach that stationary point over time. A stationary point near zero implied that the country has a weak economics condition and possibly an unstable political environment. Any impact would cause a large turbulence to the country. As a result, this country would be defenseless when facing changes in social and environmental factors. So we think this solution curve exhibits similar behavior as a fragile country.
- **One stationary point, far from 0.** This is the case of the top curve in Figure 2, which shares a pattern similar to a stable country. This can be largely explained by two reasons:
  - The stationary point is a stable equilibrium; M is always attracted to it. A stable country has a strong economy and an appropriate management; small changes in the society or environment would not prevent the country from returning to its equilibrium state.
  - If a country deviates from the equilibrium because of some accidents, its rate of recovery is substantially greater than that of a fragile state. This means that a stable country will recover much faster than a fragile country.
- **Three stationary points.** We consider it representative of a vulnerable country. The two points at either extreme are locally attracting, the one near zero representing a fragile state and the much larger one representing a stable state. The middle stationary point is repelling. This characterization suggests that when an incident happens in a vulnerable country, the country could improve its current condition and become more stable or else fail to meet the challenges and tend to become a more fragile state, depending on the incident.

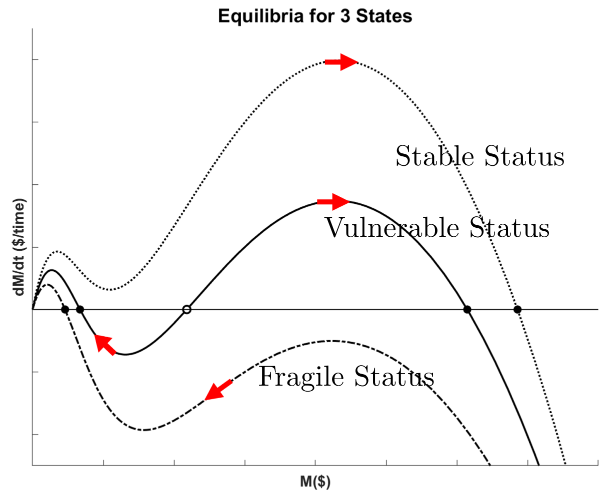

Figure 2: This figure depicts the relationship between M and $\frac{dM}{dt}$. The equilibria occur when $\frac{dM}{dt} = 0$, which are the intersects on the horizontal axis.

Parametric Plot of the Parameters

We differentiate both sides of (7):

$$\frac{d}{dx}\left(r(1-\frac{x}{s})\right) = \frac{d}{dx}\left(\frac{x}{1+x^2}\right) \tag{8}$$

$$-\frac{r}{s} = \frac{1-x^2}{(1+x^2)^2} \tag{9}$$

By itself, (7) rearranges to let us write

$$-\frac{r}{s} = \frac{1}{1+x^2} - \frac{r}{x}$$

Equating the two expressions for $-\frac{r}{s}$ allows us to solve for r, and then s, in terms of x.:

$$s = \frac{2x^3}{x^2-1}, \; r = \frac{2x^3}{(1+x^2)^2} \tag{10}$$

We make a parametric plot of r vs. s in Figure 3 for $x \geq 0$. The plane is partitioned into three regions by the (s, r) curves. According to our previous analysis, we name each region by its corresponding state in terms of fragility.

Figure 3 is crucial to analysis of a country's fragility state. With enough data for a country, we can convert the data to (s, r) using our composite index and then use the graph to tell the current state of that country. We conduct three case analyses in the next section.

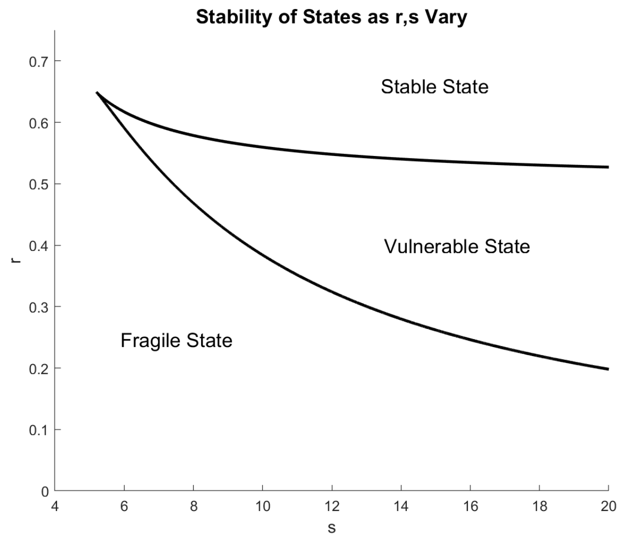

Figure 3: This figure is a parametric plot of (s, r), where s and r are expressed as a function of x. The $s - r$ curve represents the occurrence of a saddle-node bifurcation. In the *Stable State*, there is only one equilibrium; in *Vulnerable State*, there are three; in *Fragile State*, there is one.

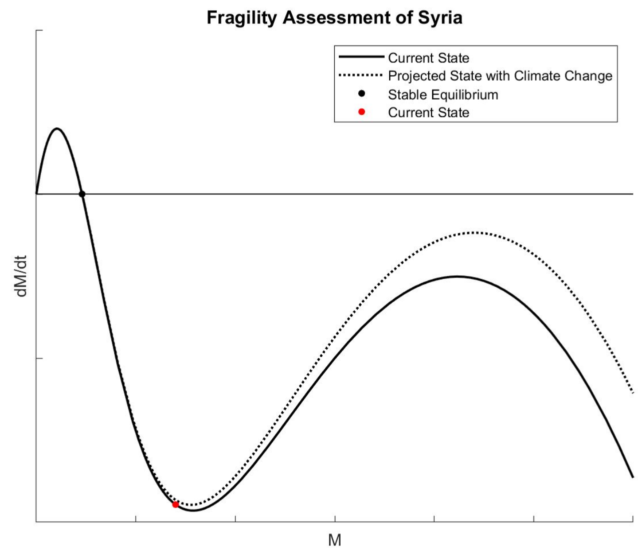

Figure 4: This figure shows the fragility assessment of Syria and its current status in $M - \frac{dM}{dt}$ plot. The model predicts that Syria would have a negative growth rate and become more fragile.

Country Analysis

Syria

Syria is one of the top 10 most fragile countries in the world. Its relatively weak economy system is one of the main reasons that make it fragile. In 2016, Syria's GDP per capita was slightly less than \$3000 and ranked at 194 out of 229 countries, according to CIA's record. The economy system of Syria depends highly The decline of oil production as a result of civil war had a major impact on Syria's economic status: . As IMF points out, oil exportation contributes to approximately 25% of the national income (International Monetary Fund, 2010). Hence, the declination of oil exploration had a major impact on Syria's economic status. After the regulation on oil exploration and the decreasing amount of oil supply, the oil production in Syria has decreased rapidly from 2005 to 2015. It suffers from an annual growth rate of -24.5% during the decade from 2005 to 2015, and does not show any sign of recovery (BP Global, 2017). Furthermore, the increasing consumption of oil turned Syria to an oil importer rather than an exporter in 2013.

Another major reason that makes Syria fragile is its political situation. The civil war in Syria caused approximately 100,000 civilian death and more than 400,000 total death (Syrian Observatory for Human Rights, 2017). More than 4 million Syrians became refugees because of the civil war. The climate condition in Syria also restricts its economic development. With a large proportion of desert, Syria suffered heavily from the water supply scarcity. More than half of the area in Syria has less than 25 centimeter of annual rainfall, and drought was not uncommon in Syria. Although Syrian could plant olives and cottons, which are the major exportation of agricultural goods in Syria, agriculture was very much restricted in varieties and quantities because of the rarity of water. The climate condition in the region around Syria also causes regional tension because of the water supply shortage, and this further causes problems in its economic development (Gleick, 2014).

Now, to determine how the climate change increased fragility of Syria, we replace its current climate value with the global average, and the resulting graph is shown above. Figure 4 shows that although Syria is still in a fragile state, its fixed point becomes a bit larger, which indicates that in the long term, the economic status of Syria will be better if it does not suffer from harsh climate conditions. Also, we can see that the curve shifts upward compared to the one accounting for climate condition, and this implies that its decreasing rate will be slower than it is right now.

Looking back at Equation 4, since we have calibrated the climate variable, the parameter k and A will change consequently. Since k is positively associated with climate condition, k value will increase after we omitted negative effect of climate. This is similar for A. Hence, we would expect r-value to increase because of increase in A, and s-value will not increase by much because s is proportional to $\frac{k}{A}$ though k increases slightly more than A. If we recall $s-r$ plot, the position of Syria would become closer to the vulnerable state than when we considered climate. This also corresponds to our research that harsh climate condition played a significant role on making Syria fragile, causing conflicts with neighboring countries as well as restricting economic growth. For example, limited water resources could cause a potential shortage of water supply and food supply, which will cause internal displacement and even panic (Gleick, 2014).

Cuba

The Fragile state index of Cuba ranks 119th out of 178 countries. FSI categorizes Cuba in the list of "warning" countries and describes Cuba as the most improved country of the past 10 years due to its economic and political reforms (Marshall and Cole, 2017).

Nevertheless, from 2008 to 2015, investment in Cuba decreased by 17%, exports has fallen by 5% and real GDP has dropped by approximately 1%. Moreover, largely due to the financial crisis in Venezuela, Cuba still has a fiscal deficit of 10.1% of GDP (the deficit in U.S. is 3.4% of GDP in 2017 according to Central Intelligence Agency Database). So, despite other improvements, Cuba's remaining debts, the U.S. embargo, restrictions on eligibility of Foreign Direct Investment and Cuba's dual currency system still pose a huge challenge to the country's economic development and growth in the future.

However, our data show that the main reasons that have dragged down Cuba are the occurrence of natural disasters and droughts. By replacing these two factors with the global average of those metrics, we see an increase in our climate parameter, which increases parameter k and A. With analysis similar to the case of Syria, we would expect both r and s to increase slightly and to help Cuba to approach the favorable stable state at the right of Figure 5. We see an upward shift of the curve in the figure, which shows that Cuba would have become slightly

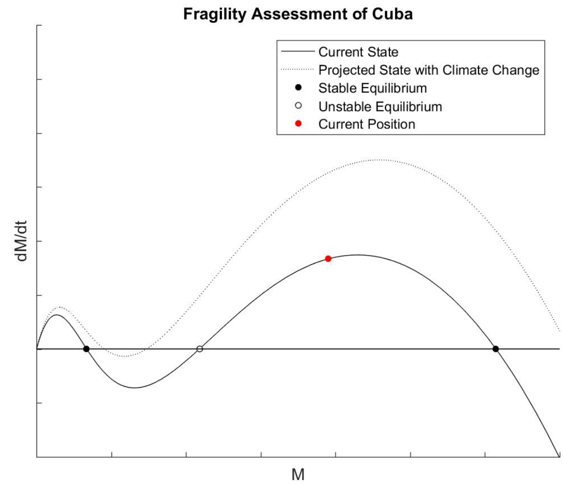

Figure 5: This figure shows the fragility assessment of Cuba and its current status in $M-\frac{dM}{dt}$ plot. The model predicts that Cuba would maintain a high growth rate.

more stable if its rainfall has been normal and it had not suffered unusual natural disasters. The (s,r) plot further confirms this.

Cuba will reach a tipping point and become a stable state when r or s increases enough. Since $s=\frac{km_2}{A}$ and $r=\frac{Am_1}{B}$, to increase r or s we could increase k, increase A, or decrease B. Since B is relatively robust, we consider how to increase k and A. Since k is positively associated with climate, policy and demographics, we would expect Cuba to reach tipping point if it could implement better political environment. It is difficult to change the climate or the demographics, so we will not discuss change of these two variables. As for A, since it is positively associated with the economic status, climate, policy and demographics, Cuba will reach tipping point if the economic status and political environment are improved.

New Zealand

New Zealand's fragile state index ranks 169th out of 178 countries, meaning that it is far from fragile. FSI recognizes New Zealand as one of the "sustainable" countries. Sustainable development has been the central focus for the government (The Heritage Foundation, 2018).

Initiatives such as new air quality standards, improvements in sewage systems, closure of substandard landfills, and clean-up of priority contami-

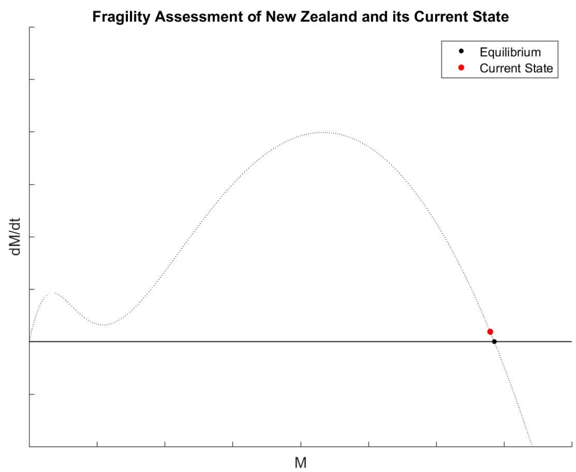

Figure 6: This figure shows the fragility assessment of New Zealand and its current status in $M - \frac{dM}{dt}$ plot. The model shows that New Zealand is slowly approaching its equilibrium.

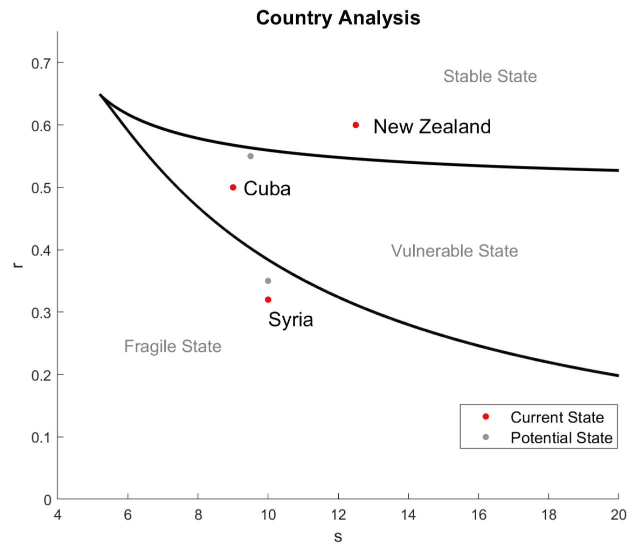

Figure 7: This bifurcation plot positioned three countries at their current states and shows the potential change of position.

nated sites are leading to measurable improvements in the quality of air, water and land resources (Bebbington et al., 2009). The government makes considerable efforts to address threats to natural resources.

New Zealand has an open and export-driven economy, with exports accounting for 30% of GDP. Its economy has been growing steadily recent years. New Zealand has strong fiscal monetary policy frameworks and a healthy financial sector, which have yielded macroeconomic stability (OECD, 2015). Although New Zealand's economy slowed during the 2008 financial crisis, the economy quickly recovered in 2010.

New Zealand's political system is based on the British model and is considered to be relatively stable. Democratic engagement is strong and 75-80% of New Zealanders turn out to vote in general elections.

Figure 6 shows a fragility assessment of New Zealand. New Zealand is currently in the stable state and is slowly approaching the attracting stationary point. This finding confirms our expectation based on our research and suggests the robustness and validity of our framework.

Bifurcation plot for the Countries Analyzed

We show in Figure 7 the parametric plot of r vs. s with the current and potential fragility state of Syria, Cuba, and New Zealand plotted. We see the position of Syria would have been slightly higher in r-direction, and Cuba would have had higher values of both s- and r – if there had not been climate change. These findings correspond to what we have discussed above, that both Syria and Cuba would have been better off with their value of the climate variable calibrated to the world average. Since New Zealand's climate variable is above average, we see no reason to replace it with the world average; thus, there is no change of position of New Zealand on this parametric plot.

Human Intervention

We think human intervention, both positive and negative, can be reflected by the political indicators. For example, when a country prioritizes economic growth via manufacturing, it may overlook the environmental policies and sustainable growth. Therefore, it would take more human effort than expected to mitigate the risk of climate change, including not only unexpected natural disasters but also effects on long-term sustainable developments.

We examine the impacts and costs of human intervention in Cuba and use both of our empirical framework and research to show that interventions can alleviate the negative market impacts of climate change and prevent Cuba from becoming a fragile state.

Extreme weather conditions has always been the primary concern for Cuba. In 2008, four hurricanes damaged 647 thousand dwellings, resulted an estimated amount of 9.76 billion pesos economic losses. The country has also suffered extreme drought which severely affected croplands and availability of water, and increased danger from fires. In 2013, 388 forest fire were reported and lost 4279 hectares of forest. Despite those direct economic losses, loss of human life has been fairly low due to government's warning and the effective Civil Defense system.

Cuba has a long history of policy initiatives to address climate change. In 2007, Cuba launched the Cuban Society Program to Face Climate Change which analyzes all sectors of the Cuban economy in terms of vulnerability to climate change and required adaptation measures. From 1998 to 2008, environmental protection spending increased from 42 million pesos (about 1.8% of total public spending) to 336 million pesos (about 6.4% of total spending) (ElSobki et al., 2009).

Based on our model, we project that if the Cuban government is going to alleviate or even eliminate the negative effects of climate change, the total cost, which is also the magnitude of political indicators in the function, would be more than $12 billion dollars by 2025.

Discussion & Conclusion

One strength of our model is its flexibility. All the parameters are relatively independent of another. Hence, it is easy to change metrics without making major changes to our model. Besides, this helps us to use our model to predict what happens if we adjust one or some of the parameters, and thereby making predictions for future.

Another strength is that it fits the result from Fragile State Index, which shows the accuracy of our model.

However, there are also limitations. One limitation is that the weight of each parameter may need to be revised to make this model more accurate. Also, we did not account for the interaction between countries, which may play an important role in evaluating fragility of some countries.

Our model can be used to evaluate fragility of small "states", such as cities. However, it may be difficult to use our model to evaluate fragility of larger "states," such as a continent, because we would have to change the definition of some data, for example, corruption or currency devaluation.

We have developed a framework that measures the fragility of a state, taking account of economic, political, demographic factors and climate change. Our framework accounts for a composite measure of major metrics and uses logistic equations to represent the positive and negative market impacts of those factors with carrying capacities. To check the robustness and validity of our model's results, we selected three representative countries, Syria, Cuba and New Zealand. Our results agree with the ranking by Fragile State Index, where Syria, Cuba and New Zealand are considered to be fragile, vulnerable and stable, respectively. Moreover, we further analyze the impacts of climate change by calibrating our metametrics and evaluating the potential level of selected countries.

Appendix

Economic Metrics

- **Collapse/Devaluation of Currency.** There is no worldwide index for devaluation of currency, although we have Euro Currency index and US Dollar index. Our approach to tackle this is to use the exchange rate of each country with respect to US dollar and calculate the change of the exchange rate for each year. We obtain exchange rate data from OECD over the period of 2000-2017.
- **Consumer Confidence.** Our group uses *Consumer Confidence index* retrieved from OECD to represent the consumer confidence in each country. The data is updated either monthly, and is based on household's decision on major purchasing and their economic status in near future. We can use this to predict the economic development in short term.
- **Foreign investment.** *Foreign direct investment, net inflows (% of GDP)* dataset is collected by the World Bank from 1970 to 2016. This shows the confidence of foreign investors for the country.
- **Government Debts and Deficits.** *General government deficit* is available on OECD over the period of 2000-2016. It can be used as an indicator of how stable the government is.

Uneven Development

The uneven development metrics considers the structural inequality based on group, education, economic status and region. Not only actual inequality but also perceptual inequality are considered since perceived inequality can also aggravate the tensions within the communities and society. This uneven development also includes opportunities for groups to improve their economic status though access to employment and education.

- **Gini Coefficient.** *GINI index* from 1979-2015 can be retrieved from World Bank. This is a major metrics measuring the unbalance of distribution of wealth in a country, where 0 represents perfectly equal and 100 represents perfectly unequal.
- **Equal Rights**. It is true that equal rights is very important as a factor to show how well people in a country live and can be calculated using the framework provided by United Nations human Rights Office of High Commissioner, but it conveys similar message as the combination of some other indicators, such as freedom of speech, health, education, corruption, etc. Hence, we will not include this indicator separately in our paper.

Political Metrics

- **Corruption.** This considers representativeness and openness of government and the perception of government by citizens. *Corruption Perception Index* over the period of 1996 to 2016 can be obtained from The World Bank.
- **Health.** This considers how well a country's health care system perform and how efficient the health care system is. We will use the ranking and data created by World Health Organization (WHO) to assess the health system of a country.
- **Education.** This measures whether people in a given country have access to essential education. *Education Index*, from United Nations Development Programme, is a good indicator of this.
- **Water.** *Basic and safely managed drinking water services* from WHO measures the percentage of population that have access to basic drinking-water services. It contains rural, urban and overall data for each country.
- **Energy.** The World Bank provides data for *Access to electricity (% of population)* from 1990 to 2014. This data can be important because it helps us understanding how well the overall energy level and this further influences the economic growth of the country.
- **Freedom of Speech.** This data measures whether people living in a country have freedom of speech. Our team uses *World Press Freedom Index* from Reporters Without Boarder as an indicator. Although this focuses mainly on press freedom, it can reflect the overall freedom as well because in most cases people have the rights to talk privately about their criticism about the government but may not be able to publish on press.

Demographic Metrics

- **Population Density** *Population density (people per sq. km of land area)* can be found from The World Bank. This measurement helps us to predict the trend of future economic development.
- **Natural Resources**. *Total natural resources rents (% of GDP)* from The World Bank can be used to represent natural resources of a country. This also helps us to predict the potential of economic development.
- **Internally Displaced Persons** *internal displacement datasets* is collected by Internally Displaced Monitoring Centre (IDMC). This dataset contains estimate of number of people displaced because of conflicts or disaster in a country.
- **Brain Drain.** *Brain Drain* data is established by Institute for Employment Research over the period of 1980-2010 (Brücker et al., 2013). This data covers the international migration information for 20 OECD destination countries by gender, country of origin and level of education. Its data contains total number of foreign-born individuals aged 25 years or older.

References

Bebbington, J., Higgins, C., and Frame, B. (2009). "Initiating sustainable development reporting: evidence from New Zealand." *Accounting, Auditing & Accountability Journal*, *22*(4), 588–625.

BP Global (2017). "Oil - BP statistical review of world energy 2017." Tech. rep.

Brücker, H., Capuano, S., and Marfouk, A. (2013). "Education, gender and international migration: insights from a panel-dataset 1980-2010." *Retrieved March*, *20*, 2014.

Davis, C., and Piccone, T. (2017). "Sustainable development: The path to economic growth in Cuba." *The Brookings Institute*.

ElSobki, M., Yasser, P. W. I., Elsobki, M., Wooders, P., and Sherif, Y. (2009). "Clean energy investment in developing countries." *Wind power in Egypt. Winnipeg, Manitoba, Canada: International Institute for Sustainable Development*.

Gleick, P. H. (2014). "Water, drought, climate change, and conflict in Syria." *Weather, Climate, and Society*, *6*(3), 331–340.

International Monetary Fund (2010). "Syrian Arab Republic: 2009 article IV consultation — staff report; and public information notice." Tech. rep.

Ludwig, D., Jones, D. D., and Holling, C. S. (1978). "Qualitative analysis of insect outbreak systems: the spruce budworm and forest." *The Journal of Animal Ecology*, 315–332.

Marshall, M. G., and Cole, B. R. (2017). "Fragile States Index methodology and CAST framework." *Global Report*.

OECD (2015). "OECD economic surveys, New Zealand."

Peters, P. (2012). *A viewer's guide to Cuba's economic reform*. Lexington Institute Arlington.

Stiglitz, J. E. (2009). "GDP fetishism." *The Economists' Voice*, *6*(8).

Syrian Observatory for Human Rights (2017). "About 500000 persons were killed in Syria during 81 months after the Syrian revolution started."

The Heritage Foundation (2018). "2018 index of economic freedom."

UNISDR (2014). "Disaster & risk profile by country." Data retrieved from https://www.preventionweb.net/english/hyogo/gar/2015/en/home/.