StateSim: Simulating war and diplomacy

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Introduction

- Computer simulation of state systems to examine hypotheses from the realist school of international relations theory
  - What factors are conducive to the stability of a state system?
  - What factors improve the survival chances of an individual state?
- Original simulation: Cusack and Stoll (1990)
- Parameters are varied over 1594 runs of the simulation, and results are subjected to survival analysis

Introduction: Outline

- What is a ‘state’? What is a ‘state system’?
- Hypotheses to be tested
- Outline of the simulation
- Statistical analysis
- Concluding remarks

What is a state system?

States:

- A singular entity that controls a body of territory and the associated resources and population
- Has a monopoly of force within this territory
- No authority greater than it, i.e., exists in anarchy
- ‘Legally’ equal to the other states
- Tries to reproduce itself by adhering to its circumscribed reason
  - Depending on the theorist: Maximizes security or maximizes power

What is a state system?

State system:

- A collection of states and their relationships with eachother
- The *de jure* and *de facto* rules of conduct between them
- The distribution of power among them

Example: Ancient Greek state system

- Urban settlements begin the 8th century BCE

Example: Ancient Greek state system, 700 BCE

Composed of 24 states

Figure 1: Ancient Greek state system c. 700 BCE

Example: Ancient Greek state system, 430 BCE

Peaks at 40 states, just as the Peloponnesian War starts between Athens and Sparta (431–405)

Figure 2: Ancient Greek state system c. 430 BCE

Example: Ancient Greek state system, 338 BCE

Universal empire—Macedonia under Philip seizes all of Greece. His son, Alexander the Great, takes them to war against the Persian Empire

Figure 3: Ancient Greek state system c. 338 BCE

Example: Ancient Greek state system and universal empire

- The final outcome of the Ancient Greek state system was universal empire
- This dynamic repeats itselfs in state systems across the world, across history
- What accounts for this?

Hypotheses

Without going in the literature of international relations theory—this simulation explicitly models the following, and seeks to determine their effect on state stability and survival:

1. Degree of inequality in power in the system
2. Evenness of economic growth between the states
3. The presence of norms of restraint, modeled as reparations paid by a war's loser to the victor
4. Accuracy of state's perception of their and other states' power
5. Destructiveness of warfare
6. Distribution of costs of war between losers and victors

The Simulation

- I'm going to focus on the mathematical part of the simulation, and breeze over substantial theoretical concerns

The Simulation: Phases

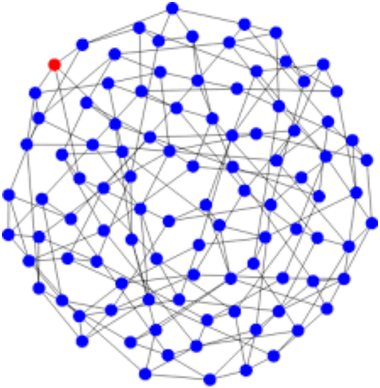
- Phase 0: Initialize the world

The next phases repeat themselves over 1000 iterations

- Phase 1: Select a ‘protagonist’ state
- Phase 2: Diplomacy
- Phase 3: War (potentially)
- Phase 4: Power adjustment / economic growth

Simulation: Phase 0: Initialize the world

States represented as nodes in a random regular graph network ($n = 98$, $p = 8$), where the edges are the borders



Simulation: Phase 0: Initialize the world

- Each of the 98 states are assigned a power resource randomly from a normal distribution with $\mu = 10$
- Standard deviation is a parameter in the model

Simulation: Phase 1: Protagonist state

- One state is randomly selected as the ‘protagonist’ of the turn
- The probability of selection is proportional to their power within the system

Simulation: Phase 2: Diplomacy

- The protagonist state examines all the states it borders, tries to find the one it has the most power over
- States do not accurately estimate eachother's power, but according to the equation:

$$E_i(p_j) = p_j \times (1 + randnorm(0, \sigma_{perception}))$$

where $\sigma_{perception}$ is a simulation parameter

Simulation: Phase 2: Diplomacy

- If the protagonist feels sure they are more powerful than the target state, a series of diplomacy occurs
- The target state tries to get allies to ward off the protagonist state
- The protagonist state builds its own alliances in turn

Simulation: Phase 2: Diplomacy

- State alliance behavior is very naive: A state only agrees to become an ally if it considers it to be the winning side
- When given an alliance proposal, a state assesses the power of the proposed alliance with $\sigma_{perception}$ as above

Simulation: Phase 3: War

- The protagonist state has three chances to back down and avoid war over the period of this alliance building
- If it does not back down, war ensues

Simulation: Phase 3: Who wins a war?

- The key variable is the *power differential* between two states or alliances
- However, we want to leave room for other factors, including random chance
- The simulation parametizes this as $\sigma_{victory}$

Simulation: Phase 3: Who wins a war?

- Likelihood of victory (LV) is modeled as a logistic curve, where steepness is controlled by the parameter $\sigma_{victory}$

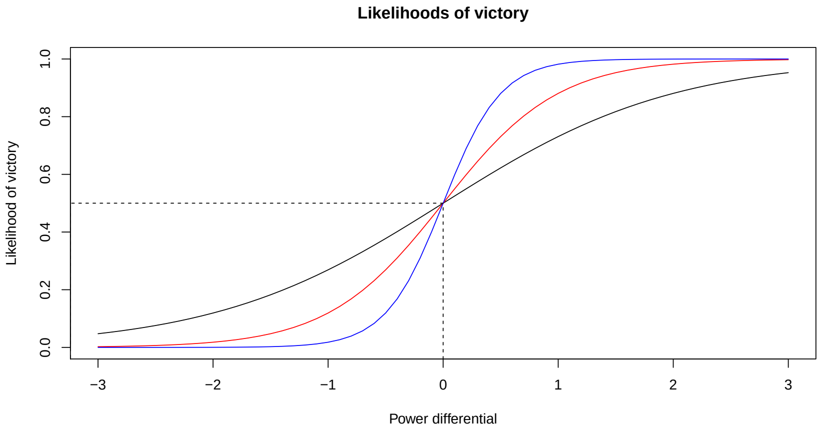


Figure 4: sigma_{victory} = (1, 2, 4) for black, red, and blue, respectively.

Simulation: Phase 3: Who wins a war?

- Thus LV is the area beneath one of these curves, between negative infinity and the power differential $ln(p_i/p_j)$

$$LV_{ij} = \frac{1}{\sqrt{\pi\sigma}} \int_{-\infty}^{ln(p_i/p_j)} e^{-(x/\sigma)^2} \, dx$$

Simulation: Phase 3: Costs of war

- Both sides must incur a cost
- The losing side should incur a higher cost
- Costs are proportional to power differential
  - War between evenly matched states is the most destructive

Simulation: Phase 3: Costs of war

- First, the 'base' cost of the war:

$$C_i = \left(1 - \frac{LSR - 0.5}{0.5}\right) \times C_{max}$$

- where LSR is a ratio of the stronger side's power to the weaker side's power:

$$LSR = \frac{max(p_i, p_j)}{p_i + p_j}$$

- and C_{max} is a parameter controlling the max cost of war

Simulation: Phase 3: Costs of war

- Second, the winner/loser modifier:

$$C_{stronger} = C_i - (min(randnorm(0,1) \times C_{max}, C_{disparity}))$$

$$C_{weaker} = C_i + (min(randnorm(0,1) \times C_{max}, C_{disparity}))$$

- where C_{disp} is the disparity parameter

Simulation: Phase 3: Spoils of war

- A portion of the losing alliance's remaining power is transferred to the winning coalition

$$S = \mathit{reparations} \times p_j$$

- where *reparations* is a parameter between 0 and 1

Simulation: Phase 3: The Versailles rule

- The leader of the losing state transfers a percentage of their power to the winning side equal to LSR
- Termed the 'Versailles' rule, it can be quite onerous
- Is a parameter in the simulation
- This is done to maintain compatibility with the original Cusack and Stoller simulation

Simulation: Phase 4: Power adjustment

- States' economic growth is pulled randomly each turn from a Cauchey distribution with mean and standard deviation as model parameters
- Stoll and Cusack originally used a normal distribution, which results in exponential growth; economic depressions are more frequent than predicted by a normal distribution

Simulation: Phase 4: Power adjustment

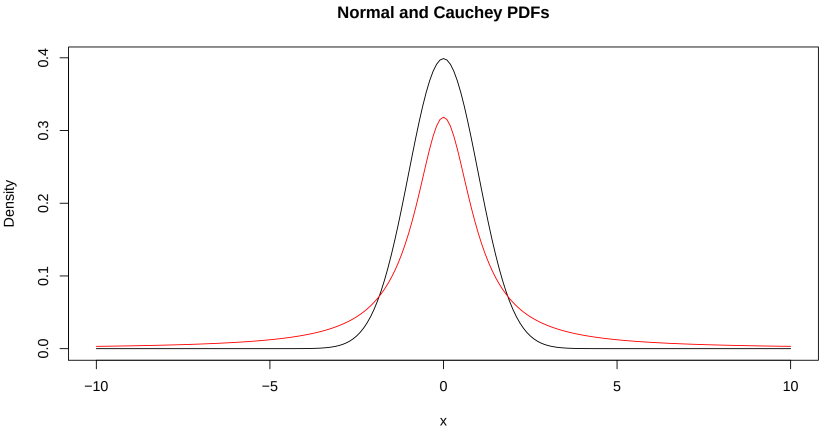


Figure 5: Cauchey (red) distributions has a thicker tails than the normal distribution (black).

Statistical analysis

- Survival analysis: Let $\mathbf{X}$ represent the parameters of specific simulations
- Modeling formula for state systems as the unit of analysis:

$$\text{Turns to universal empire} \sim \mathbf{X}$$

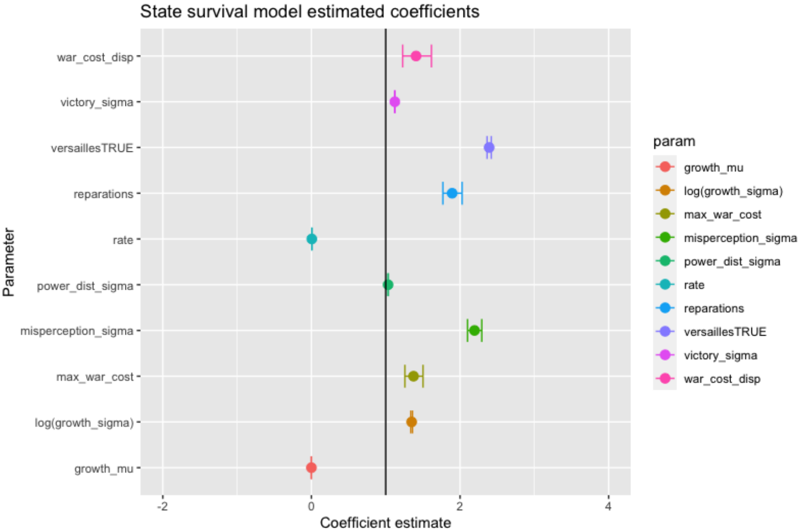
- Modeling formula for individual states and their survival time:

$$\text{Turns to state elimination} \sim \mathbf{X}$$

Survival analysis

- Not the main focus of this presention so I won't go into in depth
- Models *time to event* as the dependent variable (e.g., death, customer churn)
- I use parameteric survival analysis, modeling state and system survival as an exponential curve
  - Tried to use nonparametric Cox Proportional Hazards model, did not work out well

Statisical analysis: State survival estimated coefficients



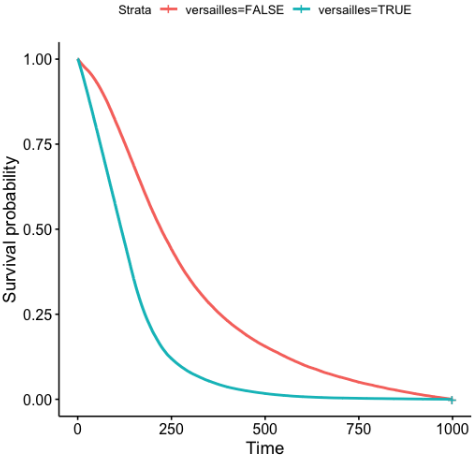
Statisical analysis: Interpretation

- Standard errors that cross 1 indicate not significantly different than 0
- Greater than 1 means increasing variable *decreases* survival time, i.e., negative relationship
- Less than 1 means increasing variable *increases* survival time, i.e., positive relationship

Statistical analysis: Effect of the Versailles rule

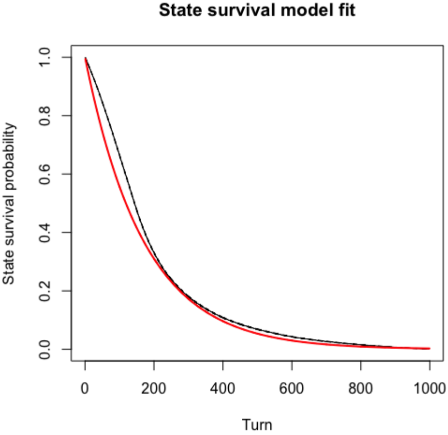
Median state survival time:

- Versailles=FALSE: 222 turns
- Versailles=TRUE: 116 turns

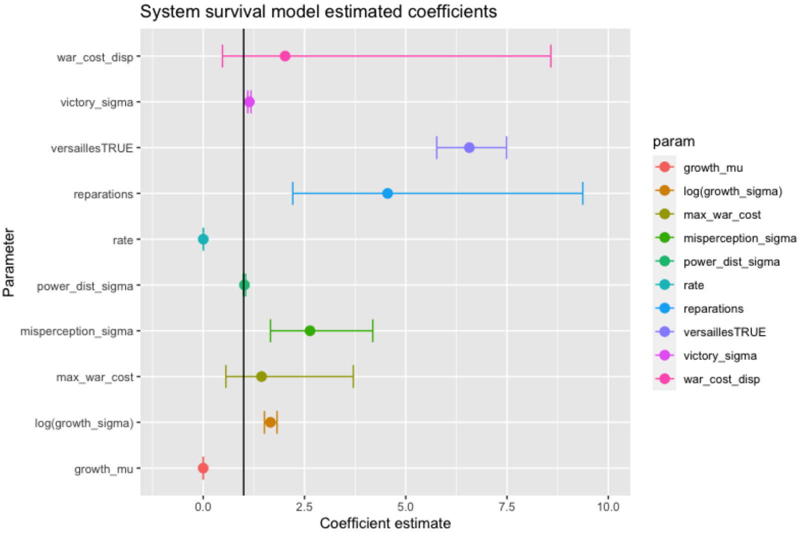


Statisical analysis: Validation

- Plot the (parametric) model's hazard rate against non-parametric Kaplan-Meier curve
- Agreement indicates good model fit

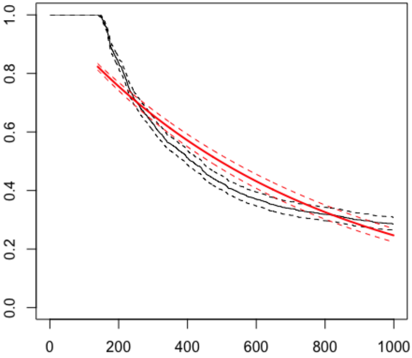


Statisical analysis: System survival estimated coefficients



Statisical analysis: Validation

- As obvious from the wide confidence intervals, not a great fit
- Interestingly, the authors of the original simulation were unable to get a good fit for their own model of state survival using Tobit regression



Conclusion

- Without going into international relations theory:
  - Simulation has shown that even under very simple assumptions about state behavior, the effects of economic growth, norms of restraint, misperception, etc., have a very real effect on system stability and state survival
  - *Contra* the realist theories that suggest none of those matter

Code

Python 3 code, paper, and records of all 1594 simulations are available at:

https://github.com/benhorvath/statesim/

The key reference for the original simulation is:

- Thomas R. Cusack and Richard J. Stoll (1990), *Exploring Realpolitik: Probing International Relations Theory with Computer Simulation* (Lynne Rienner Publishers)