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

Hypotheses: Realism

- Within the realist school of international relations, different theoriests propose contradictory answers for each of the hypotheses above
- Despite pledging fidelity to the same (?) body of theory!
  - The simulation thus functions primarily as a test of *internal consistency*, ruling out theories that contradict themselves

The Simulation

- I'm going to focus on the mathematical part of the simulation, and breeze over more technical aspects

The Simulation: Entities

There are two central object classes to this simulation:

1. `State`, representing individual states
2. `System`, representing the 'world'

The Simulation: Phases

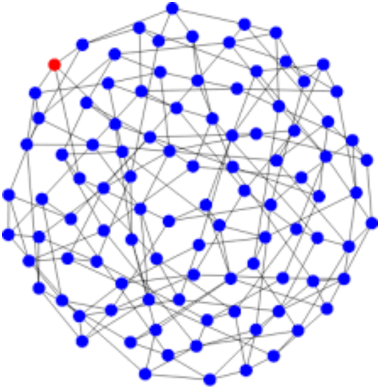
- Phase 0: Initialize the world

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 on the winning side
- State's accept or reject alliances independently of other states' decisions
- 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 $\sigma_{victory}$

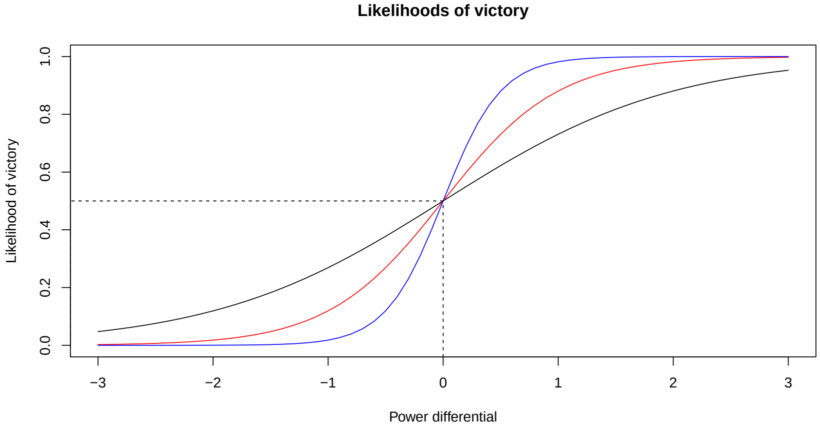


Figure 4: sigma_{victory} = (1, 2, 4) for black, red, and blue, respectively.

Simulation: Phase 3: Who wins a war?

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

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

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 $C_d isp$ 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

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

- where *reparations* is a parameter controling the reparations weight

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

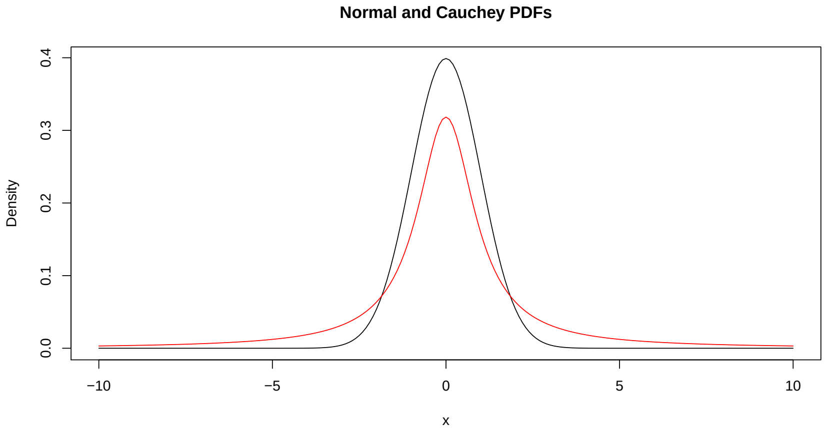


Figure 5: Cauchey (red) distributions has a thicker tails than the normal distribution (black).

Statistical analysis

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

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

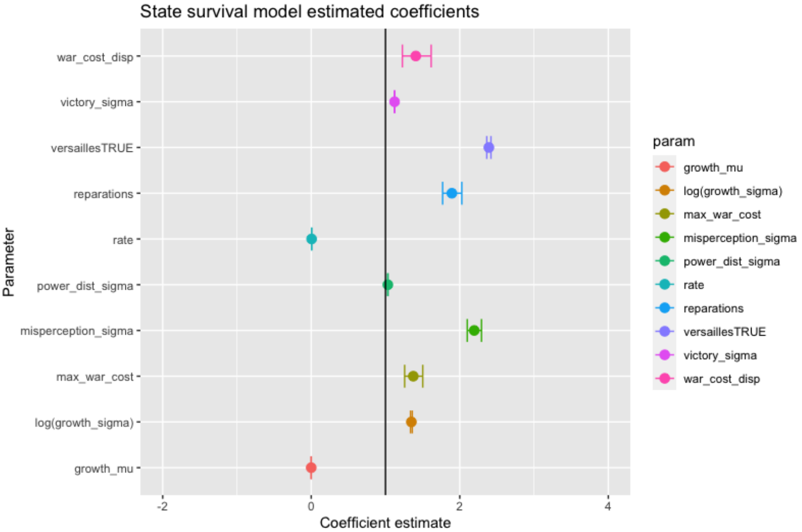
- Modeling formula for individual states and their survival time:

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

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



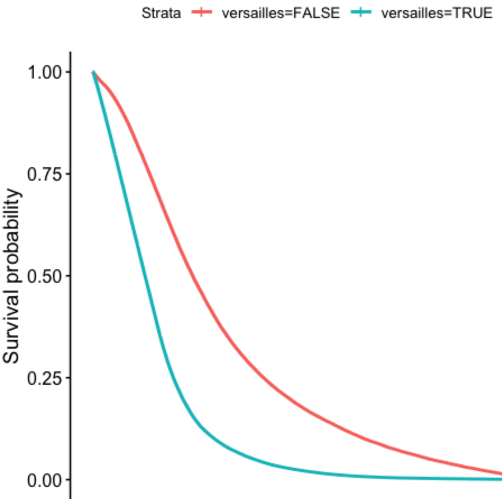
Statisical analysis: Interpretation

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

Statistical analysis: Effect of the Versailles rule

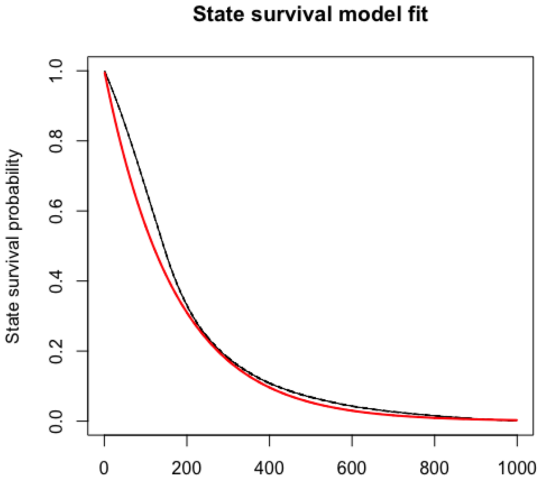
Median state survival time:

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

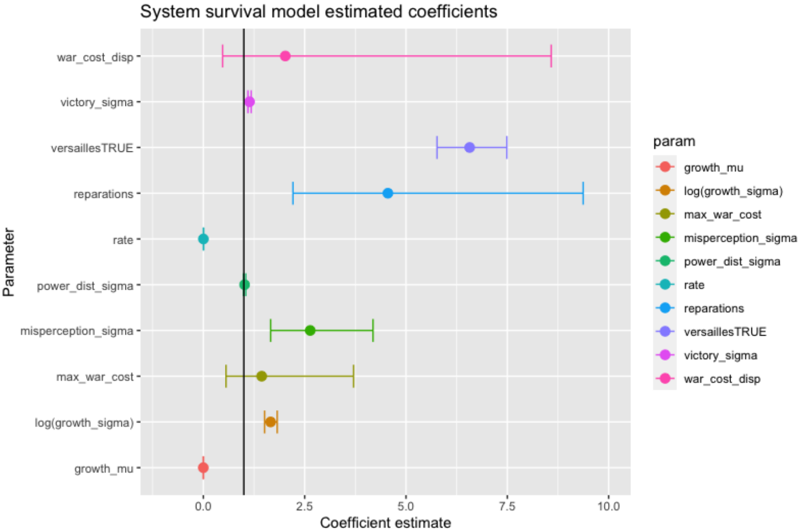


Statisical analysis: Validation

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

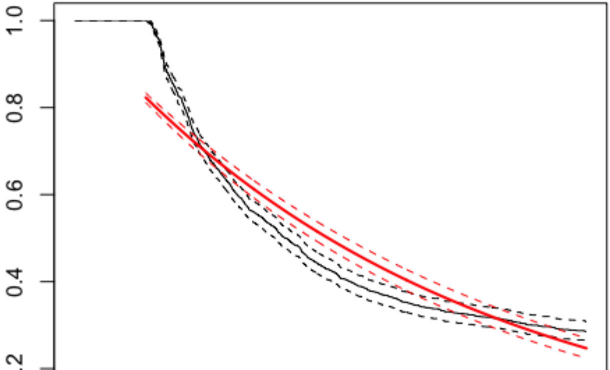


Statisical analysis: System survival estimated coefficients



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 'automatic stabilization thesis' which suggests none of these should matter
  - Simulation implies such theories suffer from logical inconsistency

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)