Computational Models of IR

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Cederman (APSR, 2003)

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- Question: what underlying mechanism(s) could explain this empirical regularity.

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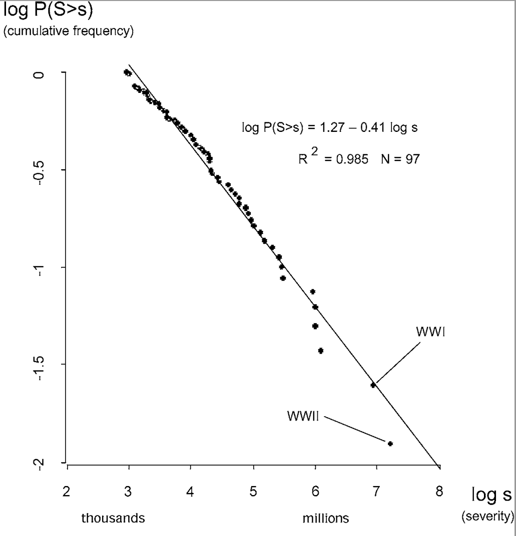
- $P(S > s) = Cs^D$, where C is positive and D is negative.
- $\log P(S > s) = \log C + D \log s$.

FIGURE 1. Cumulative Frequency Distribution of Severity of Interstate Wars, 1820–1997



Source: COW data.

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- Interstate War

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- Locally=Von Neumann neighborhood.

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- It accumulates only a share of these resources (more on this below).

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- Creates strategic interdependence.

Decision Rules

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- Unprovoked attacks happen probabilistically when a state has a 3:1 power advantage against a neighbor.

Context Activation

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- If on high alert, states attempt unprovoked attacks every time period.

Conquest

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- If the targeted province was the capital, the state collapses.

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Technological Change

- Shifts the loss-of-strength gradient such that tax extraction and power projection increases.

Counting Wars

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- Battle damage is 10% of the resources allocated to a particular front.

Built-In Implications

- Number of states decreases.
- Size of states increases.
- Local equilibria emerge if no state wants to launch attack.
- Global equilibrium emerges if all states want to refrain from attacking.

Simulations

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- 15 runs.

TABLE 1. Replication Results Based on 15 Runs of Each System

	Slope Coefficient D			R^2			Range	N Wars
	Min.	Median	Max.	Min.	Median	Max.	(Median)	(Median)
Main results								
1. Base runs	−0.64	−0.55	−0.49	0.975	0.991	0.996	4.2	204
2. Smaller shocks[a]	−0.71	−0.62	−0.56	0.968	0.980	0.993	3.7	267
3. No shocks	−1.43	−1.32	−1.17	0.878	0.941	0.975	1.4	132
4. No context activation	−1.52	−1.34	−1.20	0.835	0.882	0.934	1.6	696
Sensitivity analysis								
5. `warShadow`=10	−0.69	−0.60	−0.53	0.966	0.990	0.996	4.2	325
6. `warShadow`=40	−0.60	−0.50	−0.45	0.970	0.989	0.997	4.2	148
7. `supThresh`=2.5[a]	−0.62	−0.53	−0.46	0.965	0.984	0.991	4.3	210
8. `propMobile`=0.9	−0.65	−0.58	−0.53	0.954	0.987	0.992	4.3	250
9. `distOffset`=0.2	−0.72	−0.52	−0.43	0.908	0.990	0.995	4.4	211
10. `distSlope`=5	−0.60	−0.53	−0.46	0.974	0.986	0.991	4.3	217
11. `nx` × `ny`=75 × 75	−0.67	−0.59	−0.54	0.987	0.993	0.996	4.6	502

Note: See Table A1 for explanations of the parameter names.

[a] Based on runs with `shockSize`=10 instead of 20.

Results

- Technological change and contextual activation are responsible for the power law distribution of war sizes.
- Model suggests that warfare follows the idea of self-organized criticality.

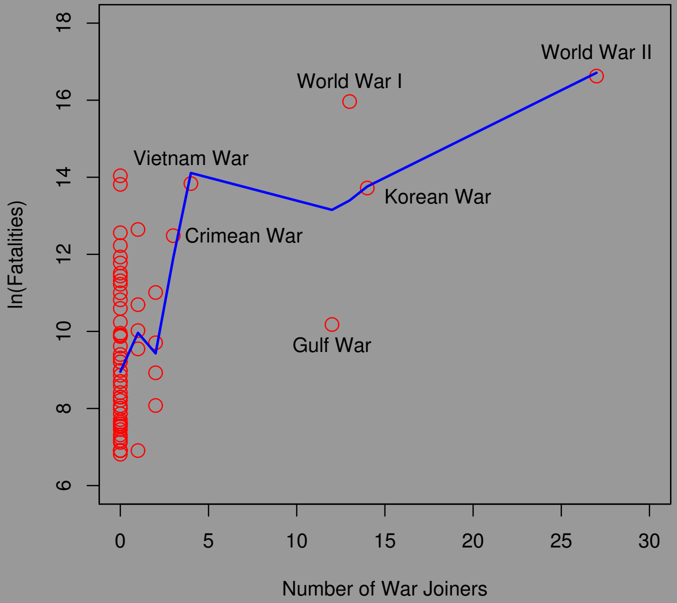
Future Research

- No alliances.
- Interaction restricted to contiguous neighbors. What about great powers?
- All wars are dyadic.

Take-Away Points

- Chose an empirical target
- Macro-historical approach
- Build in model implications that must be true
- Use illustrative runs to highlight model features
- Only turns a few model knobs
- Has shown one specification that can produce power laws
- Pseudo-code

Joyce (Working Paper)


World War II
World War I
Vietnam War
Korean War
Crimean War
Gulf War
ln(Fatalities)
18
16
14
12
10
8
6
0
5
10
15
20
25
30
Number of War Joiners

Questions

- Why do some wars expand while others do not?

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- Why do some wars expand to include a large number of additional states while others only expand to include a few states?

Empirical Targets

- 73% did not expand, 27% did expand
- Explosive expansion vs. small expansion

Two Linked Mechanisms

1. Interdependent nature of third parties' decisions

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2. Dynamics of war

An Agent-Based Model of War Expansion

Artificial International System

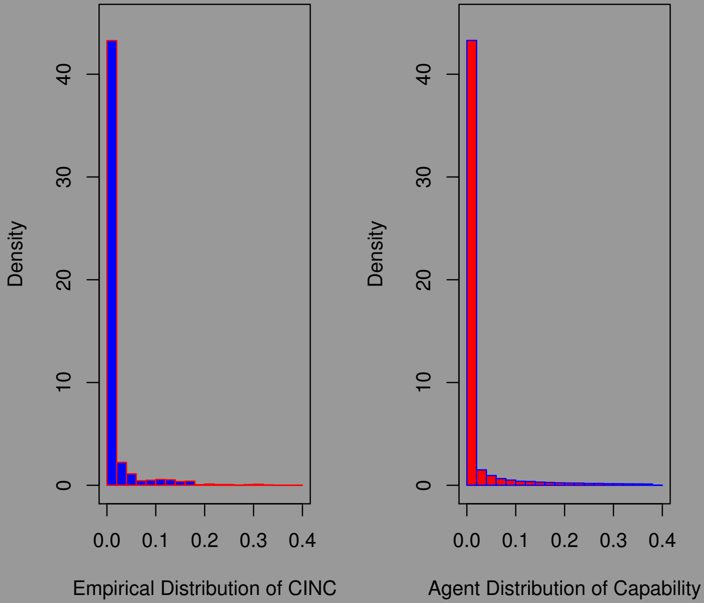
- 100 agents (i.e., states)

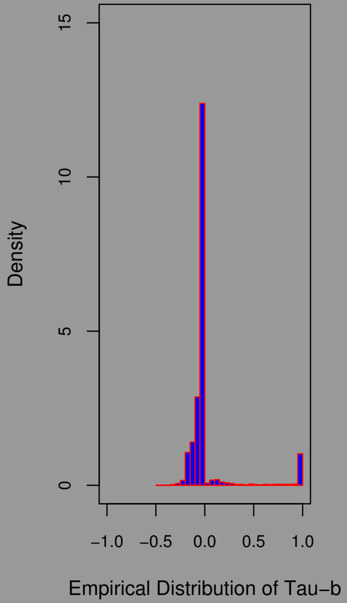
War

- Randomly select two agents (I_A and I_B) to be designated as the initial belligerents in a war

Agent Characteristics

1. Material capability (P_i, P_A, P_B)
2. Utility third-party would derive from each of the initial belligerents winning the war (α_i^A, α_i^B)


Density
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
Empirical Distribution of CINC
Density
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
Agent Distribution of Capability



15
10
5
0
Density
−1.0
−0.5
0.0
0.5
1.0
Empirical Distribution of Tau−b
15
10
5
0
Density
−1.0
−0.5
0.0
0.5
1.0
Agent Distribution

Parallel Execution

- At each time point (t) all agents simultaneously decide whether or not to join the ongoing war.
- Agents who joined in $t-1$ have to decide whether they want to remain in the war at t or exit the war.
- Agents who do not join at t have the opportunity to join at $t+1$, $t+2$, ..., T.
- Multiple agents can join at each time point (e.g., UK, France, New Zealand, Australia in WWII).
- Agents who previously joined can exit the war as it persists (e.g., Finland, Greece in WWII).

Agents' "Naive Utility" for Joining the War

- If $\alpha_i^A > \alpha_i^B$, then agent O_i prefers I_A to win and would join the war if and only if:

$$\left[\frac{\mathrm{P}_A + \mathrm{P}_i}{\mathrm{P}_A + \mathrm{P}_B + \mathrm{P}_i} - \frac{\mathrm{P}_A}{\mathrm{P}_A + \mathrm{P}_B}\right] \times (\alpha_i^A - \alpha_i^B) - c_{it} > 0 \qquad (1)$$

- If $\alpha_i^A < \alpha_i^B$, then O_i prefers I_B to win and would join the war if and only if:

$$\left[\frac{\mathrm{P}_A}{\mathrm{P}_A + \mathrm{P}_B + \mathrm{P}_i} - \frac{\mathrm{P}_A}{\mathrm{P}_A + \mathrm{P}_B}\right] \times (\alpha_i^A - \alpha_i^B) - c_{it} > 0 \qquad (2)$$

Forecasting Rule

- If an agent's naive utility is positive and $\alpha_i^A > \alpha_i^B$ the agent is forecasted to join I_A ($j \in F^A$).
- If an agent's naive utility is positive and $\alpha_i^A < \alpha_i^B$ the agent is forecasted to join I_B ($k \in F^B$).
- If an agent's naive utility is negative the agent is forecasted to remain neutral.

Forecasting Rule

- Each agent then calculates the probabilities of I_A and I_B winning the war based on which agents are forecasted to join each side:

$$p_i^A = \frac{\mathrm{P}_A + \sum_{j \in F^A} \mathrm{P}_j}{\mathrm{P}_A + \mathrm{P}_B + \sum_{j \in F^A} \mathrm{P}_j + \sum_{k \in F^B} \mathrm{P}_k} \tag{3}$$

$$p_i^B = \frac{\mathrm{P}_B + \sum_{k \in F^B} \mathrm{P}_k}{\mathrm{P}_A + \mathrm{P}_B + \sum_{j \in F^A} \mathrm{P}_j + \sum_{k \in F^B} \mathrm{P}_k} \tag{4}$$

Forecasting Rule

- Finally, each agent that is forecasted to join calculates the probabilities of I_A and I_B winning the war if all of the agents forecasted to join each side do so but they remain neutral:

$$p^A_{\sim i} = \frac{\mathsf{P}_A + \sum\limits_{j \in F^A,\ j \neq i} \mathsf{P}_j}{\mathsf{P}_A + \mathsf{P}_B + \sum\limits_{j \in F^A,\ j \neq i} \mathsf{P}_j + \sum\limits_{k \in F^B,\ k \neq i} \mathsf{P}_k} \tag{5}$$

$$p^B_{\sim i} = \frac{\mathsf{P}_B + \sum\limits_{k \in F^B,\ k \neq i} \mathsf{P}_k}{\mathsf{P}_a + \mathsf{P}_b + \sum\limits_{j \in F^A,\ j \neq i} \mathsf{P}_j + \sum\limits_{k \in F^B,\ k \neq i} \mathsf{P}_k} \tag{6}$$

Agents' Decision Rule for Joining the War

- $$\mathrm{EU}_i(\mathrm{J}) = \alpha_i^A p_i^A + \alpha_i^B (1 - p_i^A) - c_{it} \tag{7}$$

$$\mathrm{EU}_i(\mathrm{SQ}) = \alpha_i^A p_{\sim i}^A + \alpha_i^B (1 - p_{\sim i}^A) \tag{8}$$

- If $\mathrm{EU}_i(\mathrm{J}) > \mathrm{EU}_i(\mathrm{SQ})$ the agent joins I_A or I_B depending on whether $\alpha_i^A > \alpha_i^B$ or $\alpha_i^A < \alpha_i^B$ and receives a payoff equivalent to $\mathrm{EU}_i(\mathrm{J})$.
- If $\mathrm{EU}_i(\mathrm{J}) < \mathrm{EU}_i(\mathrm{SQ})$ the agent remains neutral and receives a payoff equivalent to $\mathrm{EU}_i(\mathrm{SQ})$.

Per Period Cost of Joining the War

- Fixed and stochastic component.
- Heterogeneous across agents.
- $$c_{it} = \frac{\kappa_i + \kappa_{it}}{2} \tag{9}$$
- $\kappa_i \sim U[0.00001, 0.0001]$, unique to each agent and does not vary with t (importance of war).
- $\kappa_{it} \sim U[0.01, 0.1]$, unique to each agent and varies with t (actual loss of resources).
- If an agent joins the war then the cost of joining is subtracted from their capability (P_i).

War Termination

1. When the distribution of capabilities between the two coalitions of belligerents (including the initial belligerents and any third parties that joined) exceeds the victory threshold, *and*
2. When a random number drawn from a uniform distribution exceeds the victory threshold

Simulations

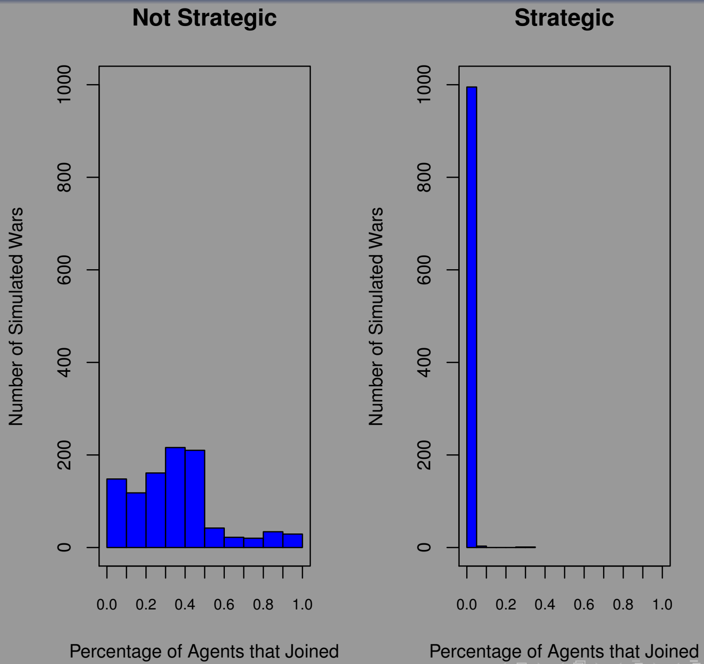
- Conducted simulations with and without the forecasting rule.

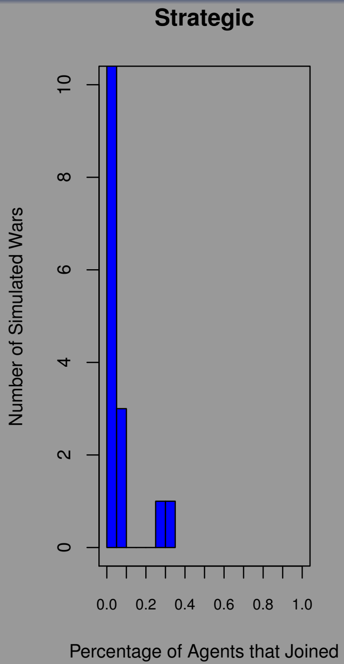
Macro-Level Patterns

- Percentage of simulated wars that did and did not expand.
- Percentage of agents in the artificial international system that joined in simulated wars that expanded.

Percentage of Simulated Wars that Did and Did Not Expand

	Not Strategic	Strategic	Empirical
Expanded	97%	22%	27%
Not Expanded	3%	78%	73%


Not Strategic
Strategic
Number of Simulated Wars
0
200
400
600
800
1000
0.0
0.2
0.4
0.6
0.8
1.0
Percentage of Agents that Joined


Strategic
Empirical
Number of Simulated Wars
Number of Wars
0
2
4
6
8
10
0.0
0.2
0.4
0.6
0.8
1.0
Percentage of Agents that Joined
Percentage of States that Joined

Results

- Most wars do not expand to include additional agents.
- Of the wars that do expand, they either expand to include a few additional agents or many additional agents.

Questions

- Why do some wars expand while others do not?
- Why do some wars expand to include a large number of additional states while others only expand to include a few states?

Answer

- Interdependent nature of third parties' decisions

Take-Away Points

- Chose an empirical target
- Micro-level approach (in contrast to Cederman)
- Assign agent characteristics based on empirical data
- Small number of knobs
- Has shown one specification that comes close to the historical record