Natural Disasters, Asymmetric Exposure, and War

Why Empirical Evidence on Climate Conflict Is Mixed

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Disasters = Negative Shock to Military Capability

https://www.thecable.ng/soldiers-displaced-as-flood-hits-military-base-in-borno/

Effect of Disasters on Conflict Risks

- Disagreement in the empirical literature
    - “Consensus” on positive effects? (e.g., Hsiang et al., 2013)
    - Sensitive to the definition of conflict (e.g., Buhaug, 2010)
    - Can have pacifying effects (e.g., Salehyan and Hendrix, 2014)

1. **When** does a disaster/extreme weather event cause conflict?

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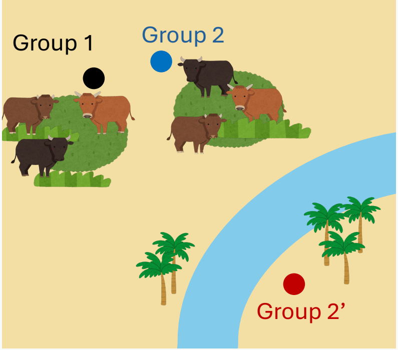
2. Why does empirical evidence on climate conflict seem **mixed**?

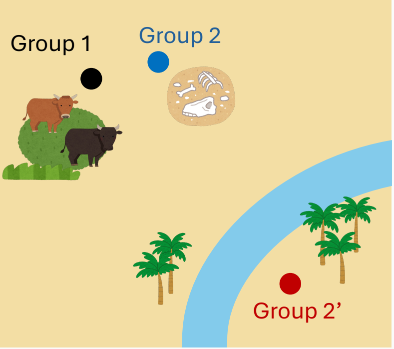
Preview of the Results

Takeaways

- Natural disasters as negative shocks to military capabilities
- Single effect generates **opposite implications** in data
- Nat. dis. **systematically make empirical evidence mixed**

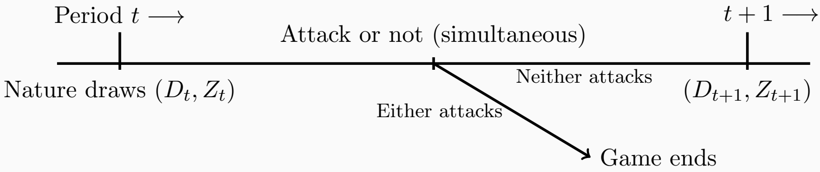
Intuition: (A)symmetric Vulnerability to Disaster Risks





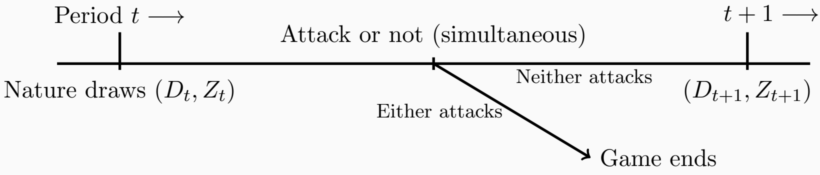
- Two dyads: Groups 1 & 2; Groups 1 & 2'
- Group 1 can have **two motives** for conflict
  - Opportunistic: Drought happens to hit 2 severely
  - Preemptive: Risk of 2''s future opportunistic aggression
- **Opposite signs** of correlation

Model Sketch



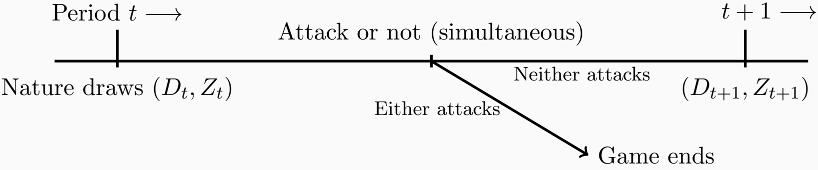
- Infinite horizon: $t = 1, 2, 3, ...$
- Two players: 1 and 2
- Complete information

Model Sketch



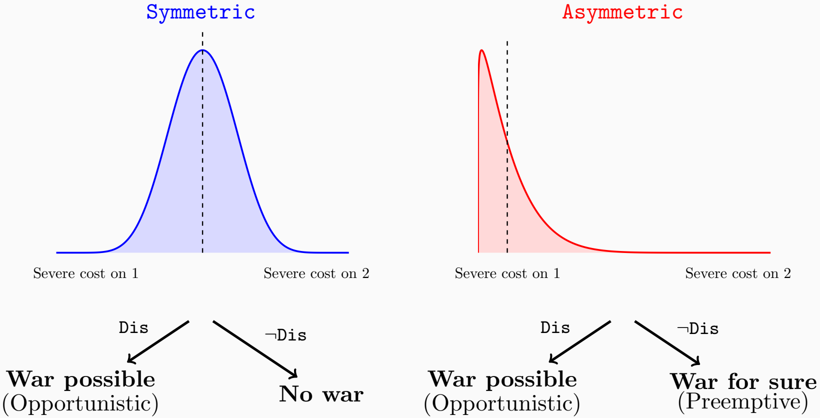
- Nature picks two random variables
  1. $D_t \in \{0, 1\}$: Absence/presence of a disaster
     - A disaster halves the resources in the society
  2. $Z_t = [0, 1]$: Relative damage from the disaster
     - Z_t small (large): Severe damage on Player 1 (2)
     - P1: $Z_t \times$ resource; P2: $(1 - Z_t) \times$ resource
- Key parameter: $\mathbb{E}[Z_t]$
  - $\mathbb{E}[Z_t] \approx 1/2$: `Symmetric` case
  - $\mathbb{E}[Z_t]$ close to 0 or 1: `Asymmetric` case

Model Sketch



- Players simultaneously choose to fight or not
  - Neither fights $\Longrightarrow$ Period $t+1$
    - Players recover from disaster damages
  - Either fights $\Longrightarrow$ Game ends
    - **Disaster affects prob. of victory**
    - Disaster: Pr(P1 wins) $= Z_t$; Pr(P2 wins) $= 1 - Z_t$
    - No disaster: Pr(i wins) $= 1/2$
- Solution concept: MPE in pure strategies
  - Strategy: $\underbrace{\{0,1\}}_{D_t} \times \underbrace{[0,1]}_{Z_t} \rightarrow \{\texttt{Attack}, \texttt{Not}\}$

Equilibrium Strategies



- **(A)symmetry in relative vulnerability** determines eq. str.

Probability of Conflict

From the theory:

$$
\begin{aligned}
&(i) \quad \overbrace{\Pr\left(\texttt{Conf}\,\middle|\,\texttt{Dis}, \texttt{Sym}\right)}^{\in(0,1)} > \overbrace{\Pr\left(\texttt{Conf}\,\middle|\,\neg\texttt{Dis}, \texttt{Sym}\right)}^{=0} \\
&(ii) \quad \underbrace{\Pr\left(\texttt{Conf}\,\middle|\,\texttt{Dis}, \texttt{Asy}\right)}_{\in(0,1)} < \underbrace{\Pr\left(\texttt{Conf}\,\middle|\,\neg\texttt{Dis}, \texttt{Asy}\right)}_{=1}
\end{aligned}
$$

- Given this, what can we say about empirical research?

Implication for Empirical Research

- Outcome = Conflict $\in \{0, 1\}$
  - $Y_{dt}(D_{dt}) = 1$: presence of conflict in dyad d at time t
  - $Y_{dt}(D_{dt}) = 0$: absence of conflict
- Treatment = Disaster **event** $\in \{0, 1\}$
  - $D_{dt} = 1$: presence of a disaster **event**
  - $D_{dt} = 0$: absence of a disaster **event**

Implication for Empirical Research

- Suppose we are interested in CATE
- Define ATE **conditional** on relative vulnerability in dyad d

$$\tau(\texttt{Vul}) \equiv \mathbb{E}\left[Y_{dt}(1) - Y_{dt}(0) | \texttt{Vul}\right],$$

where $\texttt{Vul} \in \{\texttt{Sym}, \texttt{Asy}\}$

Implication for Empirical Research

- Applying the P.O. languages to theory yields:

Implication: Negative CATE

$$\tau(\texttt{Sym}) > 0 > \tau(\texttt{Asy})$$

- What does this tell us?
  - Opposite signs of CATE, but...
  - Negative CATE because [treatment = disaster **event**]
  - Conflict still due to **disaster risks** in the `Asy` case
  - Emp. results might systematically look mixed

Summary

Theory

- **Contrasting equilibrium strategies**
- Source of contrast: **asymmetry** in relative resilience ($\mathbb{E}[Z_t]$)

New interpretation of the mixed results

- `Asymmetric` case: **negative** effect in terms of CATE
- Risk of **underestimating** the effects of disasters on conflict
- Taking **theory & DGP** more seriously

(*In the paper, I also derive a **simple but novel prediction** from the model and **connect the theory with data on political violence and droughts** in Africa)

Thank you!

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Backup slides

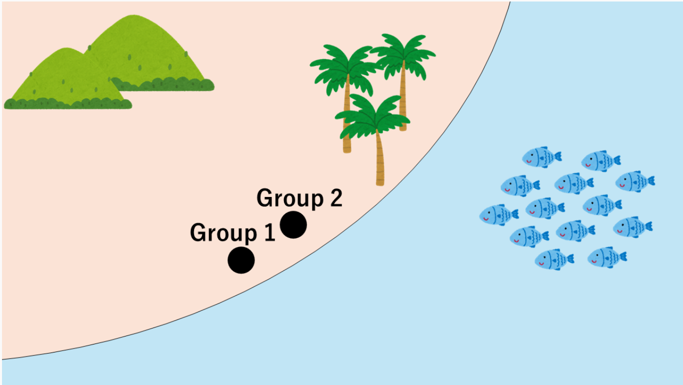
Key Assumptions

Two assumptions

- Damage from a disaster is **random**
  - One particular event might hit one region more severely
  - But groups know the distribution of expected damage
    - "We are inherently resilient/vulnerable to disaster risks"
  - Scope condition: seasonal disasters (relatively foreseeable)
- Disasters shift the balance of military power
  1. Disasters destroy resources (perhaps **asymmetrically**)
  2. Groups' resources determine war outcomes

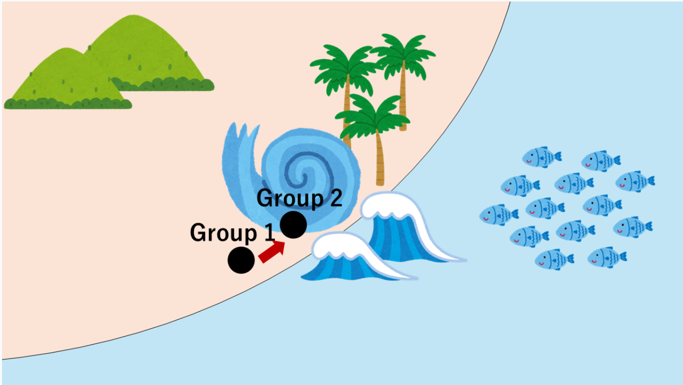
Intuition: Case (1) Realized Exposure to Disaster

- Two rival political groups
  - Geographically proximate
  - Similar resilience in economy & social infrastructure
  - Facing **symmetric** risks of natural disasters



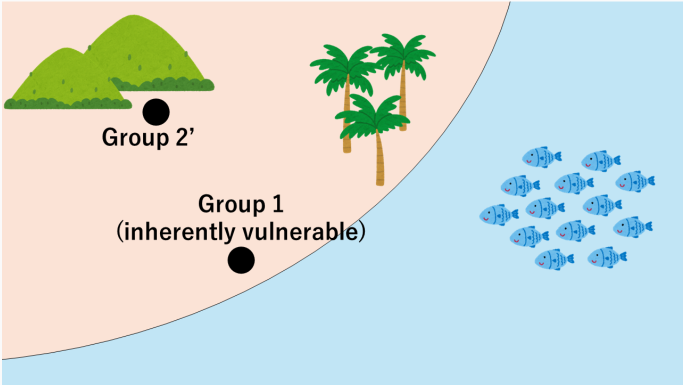
Intuition: Case (1) Realized Exposure to Disaster

- Suppose a climate anomaly hit Group 2
  - Disproportionate damage
  - Temporary power shift favoring Group 1
  - Group 1: incentive for **opportunistic attack** (Kikuta, 2019)



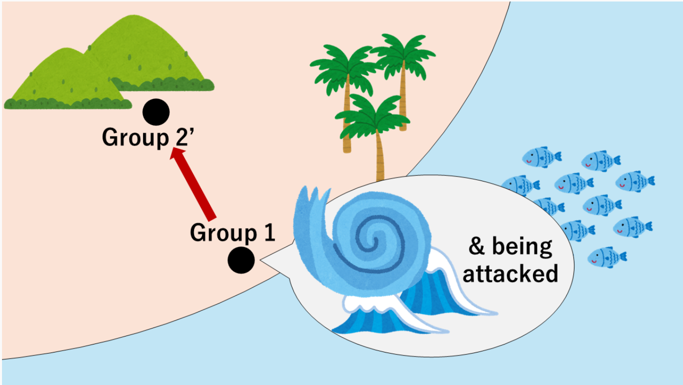
Intuition: Case (2) Expected Exposure to Disaster

- Now consider another dyad: Group 1 and Group 2'
  - Geographically distant
  - Only Group 1 on a disaster-prone coastal area
  - Group 1 is **inherently** vulnerable to disaster risks



Intuition: Case (2) Expected Exposure to Disaster

- Suppose there is **no** disaster
  - Group 2' might opportunistically attack 1 in the future
  - Group 1 **anticipates** future risk of being attacked after dis.
  - Group 1: **preventive** attack in the **absence** of dis. (Bas and Mclean, 2021)



Preview of Results: What Do the Examples Tell Us?

- Two opposing outcomes arising from a **single** dynamic
  - First case: war **right after** a disaster
    - Positive association b/w disaster event & conflict
  - Second case: war in its **absence**
    - **Negative** correlation

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Takeaway

- Overlooking the **asymmetric** case
  $\Longrightarrow$ **Underestimation** of disaster$\rightarrow$conflict causal effect
  - **Negative** CATE if "treatment = actual disaster **event**"
- Novel explanation for seemingly mixed empirical results
  - They might be **meant to be mixed**
- Need to take theory & data-generating process more seriously

Related Literature

1. Natural disasters/climate anomalies/econ. shocks & conflict
    - Theoretically making sense of mixed results
    - E.g., Bas & McLean (2021); Chassang and Padró i Miquel (2009); Kikuta (2019)

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2. Rapid power shift as a cause of conflict
    - Introducing asymmetry in the direction of a power shift
    - E.g., Little & Paine (2023); Fearon (2004); Powell (2004)

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2. Rapid power shift as a cause of conflict
    - Introducing asymmetry in the direction of a power shift
    - E.g., Little & Paine (2023); Fearon (2004); Powell (2004)
3. Theoretical implications of empirical models (TIEM)
    - Calls for a "closer marriage" of theory and empirics (Slough)
    - E.g., Slough (2023); Wolton (2019)

Outline

- This presentation:

1. Model
2. Analysis
3. Implication for empirical research
    - Today, we tentatively assume "the model explains data"
    - "What does the model tell us about emp. research design?"

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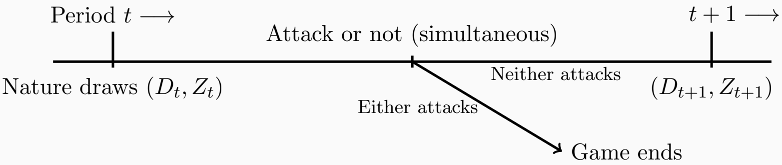
- But the paper also...
  - (i) derives an empirical prediction,
  - (ii) shows that the theory explains real-world data, and
  - (iii) discusses papers w/ conflicting results & makes sense of them

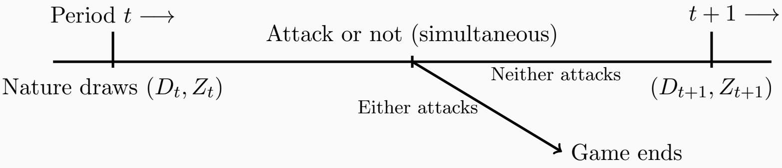
The Model

Setup: Timeline & Strategies



- Infinite-horizon, two-player game: $i \in \{1, 2\}, t = 1, 2, 3, ...$
  - Rival political groups / countries
  - <u>In each t</u>, each player has resources whose amount is θ
    - Disaster discounts resources, but players **recover** from it

Setup: Timeline & Strategies



1. Nature's moves: disaster/extreme weather event
   (1-1) Disaster: $D_t \sim \mathrm{Bern}(\pi)$
   - $D_t = 1$: disaster period (w/ prob. π)
   - $D_t = 0$: no-disaster period ($1 - \pi$)

   (1-2) Level of **asymmetry** of damage: Z_t
   - Cont. differentiable CDF F; density f; $\mathrm{supp}\, F = [0, 1]$
   - **Mean μ: key parameter** (more on this later)

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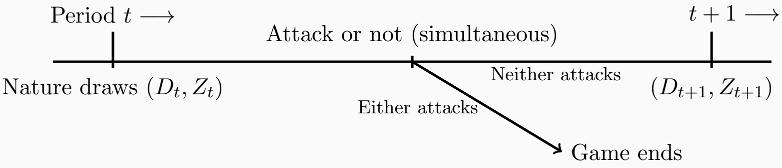

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   (1-2) Level of **asymmetry** of damage: Z_t
      - Cont. differentiable CDF F; density f; $\mathrm{supp}\, F = [0, 1]$
      - **Mean μ: key parameter** (more on this later)
2. Actions: `Attack` or `Not` (simultaneous move)
   - Either `Attack` $\Longrightarrow$ game ends
   - Both `Not` $\Longrightarrow$ next period (w/ discount factor δ)

Setup: Peace Payoffs

- Peace payoffs: no conflict at t
  - No-disaster period
    - θ for both
  - Disaster period
    - Disaster **destroys resources**
    - $z_t\theta$ for Player 1 (where z_t represents a realized value of Z_t)
    - $(1 - z_t)\theta$ for Player 2
    - Disaster halves resources in society

Setup: War Payoffs

- Conflict is a costly lottery
  - $\mathbb{E}[\text{War payoff}] = \text{Pr}(i \text{ wins}) \times \underbrace{[\text{Current gain} + \text{long-term gain}]}_{\text{Next page}}$
  - $\text{Pr}\,(i \text{ wins}) = (i\text{'s resource})/(\text{Sum of resources})$
    - No-disaster period: $\theta/(2\theta) = 1/2$
    - Disaster period, Player 1: $z_t\theta/\theta = z_t$
    - Disaster period, Player 2: $(1 - z_t)\theta/\theta = 1 - z_t$

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- Current payoffs from conflict
  - Defeat: 0
  - Victory: Winner dominates entire resource in society
    - $c \in (0,1)$: cost of war
    - $\underbrace{2\theta(1-c)}_{\text{No-dis. period}}$ or $\underbrace{\theta(1-c)}_{\text{Dis. period}}$

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    - $\underbrace{2\theta(1-c)}_{\text{No-dis. period}}$ or $\underbrace{\theta(1-c)}_{\text{Dis. period}}$
- Long-term payoffs from conflict
  - Defeat: 0
  - Victory: Long-term gain from dominance

$$
\begin{aligned}
\overline{\mathcal{V}} \quad &\equiv \quad \mathbb{E}_{D,Z}\left[\sum_{t=1}^{\infty}\delta^{t-1}\left(\underbrace{D_t\left(Z_t\theta+(1-Z_t)\,\theta\right)}_{\text{As-if disaster period}}+\underbrace{(1-D_t)\,2\theta}_{\text{As-if no-dis. period}}\right)\right] \\
&= \quad \frac{\theta(2-\pi)}{1-\delta}
\end{aligned}
$$

Setup: War Payoffs

- E.g., Player 1's expected war payoff in a disaster period

$$\underbrace{z_t}_{\text{Pr(Player 1 wins)}} \times \left[\underbrace{\theta(1-c)}_{\text{Current gain}} + \underbrace{\delta\overline{\mathcal{V}}}_{\text{Long-term gain}} \right] + \underbrace{(1-z_t)\times 0}_{\text{Defeat}}$$

- In sum, the model assumes:
  1. Disaster destroys resources
  2. Then (affected) resources determine the war outcome

Setup: Assumptions and Solution Concept

Assumption 1

- Indifferent b/w `Attack` & `Not` $\Longrightarrow$ Play `Not`
  - Excludes, e.g., equilibrium where "always `Attack`"
  - Focus on pure strategies

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Assumption 2

- Consider a pair of different distributions of Z_t
- Then, assume they are identical except for one parameter
  - e.g., $Z_t \sim \text{Beta}(\alpha, \texttt{constant})$

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Assumption 2

- Consider a pair of different distributions of Z_t
- Then, assume they are identical except for one parameter
  - e.g., $Z_t \sim \text{Beta}(\alpha, \texttt{constant})$

- Information structure: complete information
- Solution concept: pure-strategy (stationary) MPE
  - State variable: (D_t, Z_t)
  - Strategy: $\underbrace{\{0,1\}}_{D_t} \times \underbrace{[0,1]}_{Z_t} \to \{\texttt{Attack}, \texttt{Not}\}$

Key Features of the Model

- The key concept: asymmetric exposure to disasters

1. **Realized** (a)symmetry: z_t = realized value of Z_t
    - z_t large: Player 1 happens to be advantaged
    - z_t small: Player 2 advantaged
    - z_t close to 1/2: symmetric disaster costs

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    - z_t large: Player 1 happens to be advantaged
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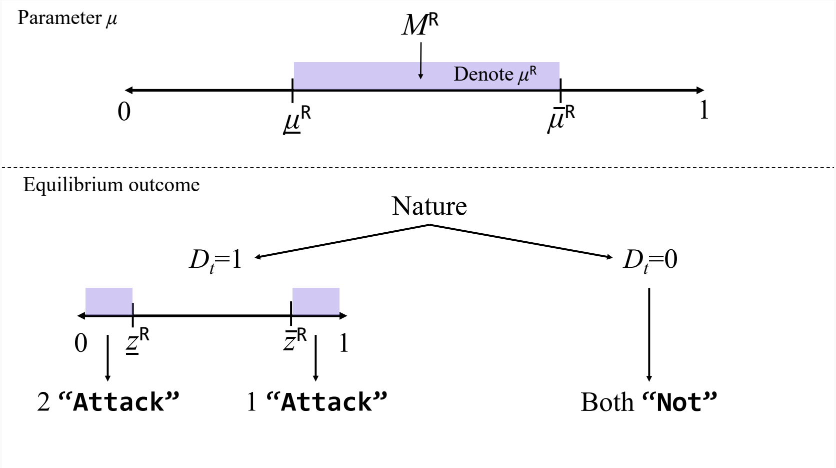
    - z_t close to 1/2: symmetric disaster costs
2. **Expected** (a)symmetry: $\mu = \mathbb{E}[Z_t]$
    - μ close to 1/2: symmetry in expected exposure
    - μ close to 0 or 1: inherent asymmetry in expected exposure

Analysis

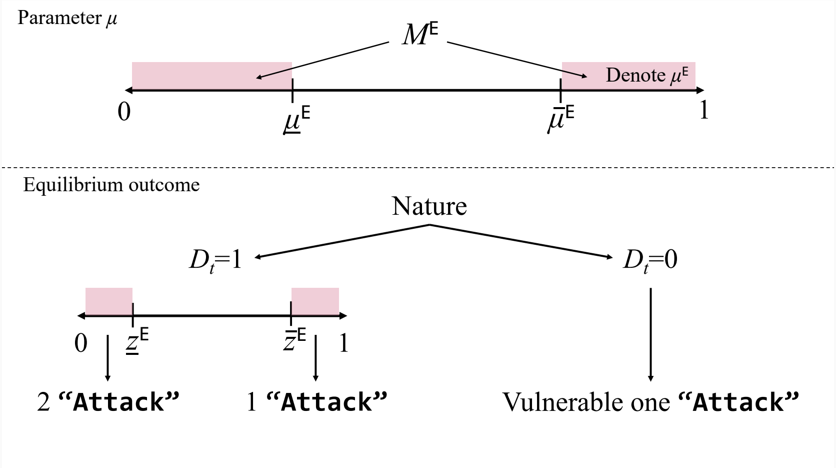
War Caused by Realized Disproportionate Damage

- Equilibrium 1: Symmetric-risk case
  - **Opportunistic** aggression

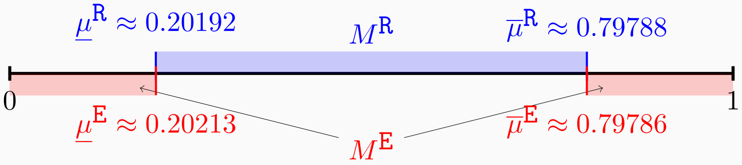


War Caused by Expected Disproportionate Damage

- Equilibrium 2: Asymmetric-risk case
  - **Preventive** attack



Summary



Conjecture

- $\exists$ Partition $\{0, \underline{\mu}^{\mathtt{R}}, \underline{\mu}^{\mathtt{E}}, \overline{\mu}^{\mathtt{E}}, \overline{\mu}^{\mathtt{R}}, 1\}$ such that
    1. $\mu < \underline{\mu}^{\mathtt{R}}$: Asym. eq. where 1 attacks when $D_t = 0$ (unique)
    2. $\mu \in [\underline{\mu}^{\mathtt{R}}, \underline{\mu}^{\mathtt{E}})$: Both (eq. multiplicity)
    3. $\mu \in [\underline{\mu}^{\mathtt{E}}, \overline{\mu}^{\mathtt{E}}]$: Symmetric equilibrium (unique)
    4. $\mu \in (\overline{\mu}^{\mathtt{E}}, \overline{\mu}^{\mathtt{R}}]$: Both (eq. multiplicity)
    5. $\mu > \overline{\mu}^{\mathtt{R}}$: Asym. eq. where 2 attacks when $D_t = 0$ (unique)

Main Implication

- Define $Y_t^{\text{game}} = \mathbb{1}\{\text{Conflict in eq. at } t\}$

Corollary 1

$$(i)\quad \overbrace{\Pr\left(\overbrace{Y_t^{\text{game}}=1}^{\text{Conflict in eq.}}\,\middle|\,\overbrace{D_t=1}^{\text{Disaster}},\ \overbrace{\mu^{\mathtt{R}}}^{\text{Sym. case}}\right)}^{\in(0,1)} > \overbrace{\Pr\left(Y_t^{\text{game}}=1\,\middle|\,\underbrace{D_t=0}_{\text{No disaster}},\ \mu^{\mathtt{R}}\right)}^{=0}$$

$$(ii)\quad \underbrace{\Pr\left(\overbrace{Y_t^{\text{game}}=1}^{\text{Conflict in eq.}}\,\middle|\,\overbrace{D_t=1}^{\text{Disaster}},\ \overbrace{\mu^{\mathtt{E}}}^{\text{Asym. case}}\right)}_{\in(0,1)} < \underbrace{\Pr\left(Y_t^{\text{game}}=1\,\middle|\,\underbrace{D_t=0}_{\text{No disaster}},\ \mu^{\mathtt{E}}\right)}_{=1}$$

- We use this result to draw:
  1. (an empirical prediction *in the paper)
  2. theoretical implications for empirical research

Theoretical Implication for Empirical Research

What does the model tell us about empirical research?

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- Tentatively assume that the model explains data
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- Here, consider the potential outcomes framework
  - Potential outcome: conflict event
    - $Y_{dt}^{\mathtt{PO}}(D_{dt}) = 1$: presence of conflict in dyad d at time t
    - $Y_{dt}^{\mathtt{PO}}(D_{dt}) = 0$: absence of conflict
  - Treatment: (actual) disaster **event**
    - $D_{dt} = 1$: presence of a disaster **event**
    - $D_{dt} = 0$: absence of a disaster **event**
  - A measure of (a)symmetry in disaster risks
    - Suppose each dyad has $\mu_d \in [0, 1]$ as in the model

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    $\implies$ Focus on CATE $= \tau(\mu) \equiv \mathbb{E}\left[Y_{dt}^{\texttt{PO}}(1) - Y_{dt}^{\texttt{PO}}(0) | \mu_d = \mu\right]$

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  - Also, recall Corollary 1

$$(i) \quad \underbrace{\Pr\left(Y_t^{\mathtt{game}} = 1 \middle| D_t = 1, \mu^{\mathtt{R}}\right) > \Pr\left(Y_t^{\mathtt{game}} = 1 \middle| D_t = 0, \mu^{\mathtt{R}}\right)}_{\text{Symmetric case: War more likely after disaster}}$$

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Assumption 3

- "The model captures the data-generating process"
- i.e., When we have conflict data $Y_{dt}^{\texttt{data}} \in \{0, 1\}$, interpret

$$\underbrace{Y_{dt}^{\texttt{data}}}_{\text{Conflict in observed data}} = \underbrace{Y_t^{\texttt{game}}}_{\text{Conflict in eq. of the model}}$$

Heterogeneous Effects in the PO Framework

Corollary 2

- By Corollary 1 and $Y_{dt}^{\texttt{data}} = D_{dt} Y_{dt}^{\texttt{PO}}(1) + (1 - D_{dt}) Y_{dt}^{\texttt{PO}}(0)$,

(i) $\Pr\left(Y_{dt}^{\texttt{PO}}(1) = 1 \middle| \mu_d = \mu^{\texttt{R}}\right) > \Pr\left(Y_{dt}^{\texttt{PO}}(0) = 1 \middle| \mu_d = \mu^{\texttt{R}}\right)$

Symmetric case: War **more** likely after disaster

(ii) $\Pr\left(Y_{dt}^{\texttt{PO}}(1) = 1 \middle| \mu_d = \mu^{\texttt{E}}\right) < \Pr\left(Y_{dt}^{\texttt{PO}}(0) = 1 \middle| \mu_d = \mu^{\texttt{E}}\right)$

Asymmetric case: War **less** likely after disaster

Heterogeneous Effects in the PO Framework

Corollary 2

- By Corollary 1 and $Y_{dt}^{\texttt{data}} = D_{dt} Y_{dt}^{\texttt{PO}}(1) + (1 - D_{dt}) Y_{dt}^{\texttt{PO}}(0)$,

$$(i) \quad \Pr\left(Y_{dt}^{\texttt{PO}}(1) = 1 \middle| \mu_d = \mu^{\texttt{R}}\right) > \Pr\left(Y_{dt}^{\texttt{PO}}(0) = 1 \middle| \mu_d = \mu^{\texttt{R}}\right)$$

Symmetric case: War **more** likely after disaster

$$(ii) \quad \Pr\left(Y_{dt}^{\texttt{PO}}(1) = 1 \middle| \mu_d = \mu^{\texttt{E}}\right) < \Pr\left(Y_{dt}^{\texttt{PO}}(0) = 1 \middle| \mu_d = \mu^{\texttt{E}}\right)$$

Asymmetric case: War **less** likely after disaster

Implication: Negative CATE in the asymmetric case

$$\underbrace{\tau\left(\mu^{\texttt{R}}\right)}_{\text{Symmetric case}} > 0 > \underbrace{\tau\left(\mu^{\texttt{E}}\right)}_{\text{Asymmetric case}}$$

Heterogeneous Effects in the PO Framework

- What does the implication tell us?

Possible underestimation of causal effects

- Some empirical frameworks might not always be suitable
- Why?
  - Treatment: actual disaster **event**
  - **Negative** effect **in the sense of CATE**
  - But theoretically, in the 2nd eq.:

$$\begin{aligned} & \text{(Asymmetric) } \textbf{disaster risks} \Longrightarrow \text{conflict} \\ = \; & \text{Disaster ``}\textbf{triggers}\text{'' conflict} \end{aligned}$$

  - Might lead to **underestimation** of effects of disasters
- Need to pay more attention to **theory (DGP)**

Conclusion

Summary

Theory

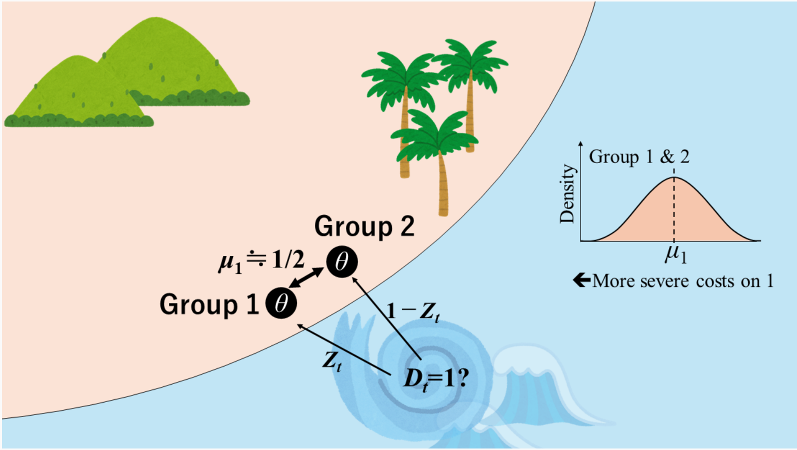
- **Contrasting equilibria** from a **single** theoretical dynamic
- Source of contrast: **asymmetry** in exposure risk (μ)

Theoretical Implication for Empirical Research

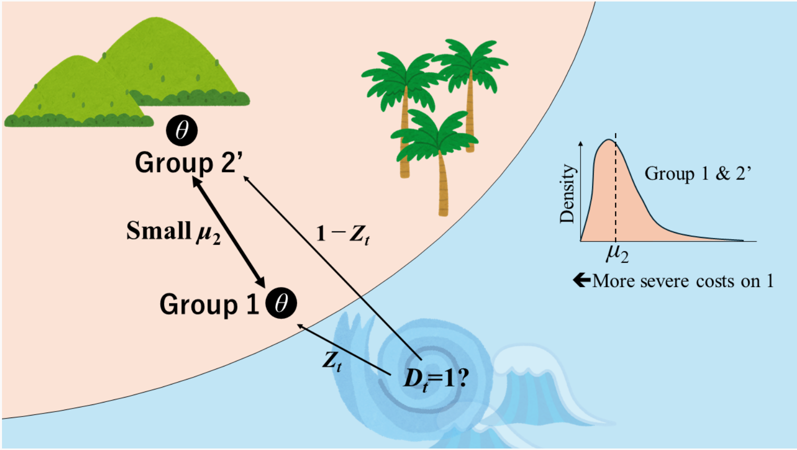
- **Negative** effect in terms of CATE
- Risk of **underestimating** the effects of disasters on conflict
- Taking **theory** more seriously

(*In the paper, I also derive a **simple but novel prediction** from the model and **connect the theory with data on political violence and droughts** in Africa)

What Does the Model Describe?



What Does the Model Describe?



Proposition on the Symmetric Case

Proposition

Consider an interval $M^{\mathrm{R}} \equiv \left[\underline{\mu}^{\mathrm{R}}, \overline{\mu}^{\mathrm{R}}\right]$, where the thresholds $\underline{\mu}^{\mathrm{R}}$ and $\overline{\mu}^{\mathrm{R}}$ are defined below. When $\mu \in M^{\mathrm{R}}$, the strategies described in the figure constitute an MPE.

- Given $\mu \in M^{\mathrm{R}}$, the thresholds above/below which one player attacks the other when $D_t = 1$ are given as the solution to the following system of equations.

$$\begin{cases} \overline{z}^{\mathrm{R}}(\mu) = & \delta \cdot \dfrac{(1-\pi) + \pi\left(\mu + \left(\int_0^{\underline{z}^{\mathrm{R}}(\mu)} z\mathrm{d}F(z) + \int_{\overline{z}^{\mathrm{R}}(\mu)}^1 z\mathrm{d}F(z)\right)\left[\delta\dfrac{2-\pi}{1-\delta} - c\right]\right)}{\left(1-\delta\left(1-\pi\left(1-\Delta_F\left(\overline{z}^{\mathrm{R}}(\mu), \underline{z}^{\mathrm{R}}(\mu)\right)\right)\right)\right)\left[\delta\dfrac{2-\pi}{1-\delta} - c\right]} \\ \underline{z}^{\mathrm{R}}(\mu) = & 1-\delta \cdot \dfrac{(1-\pi) + \pi\left(1-\mu + \begin{bmatrix} 1-\Delta_F\left(\overline{z}^{\mathrm{R}}(\mu), \underline{z}^{\mathrm{R}}(\mu)\right) \\ -\left(\int_0^{\underline{z}^{\mathrm{R}}(\mu)} z\mathrm{d}F(z) + \int_{\overline{z}^{\mathrm{R}}(\mu)}^1 z\mathrm{d}F(z)\right) \end{bmatrix}\left[\delta\dfrac{2-\pi}{1-\delta} - c\right]\right)}{\left(1-\delta\left(1-\pi\left(1-\Delta_F\left(\overline{z}^{\mathrm{R}}(\mu), \underline{z}^{\mathrm{R}}(\mu)\right)\right)\right)\right)\left[\delta\dfrac{2-\pi}{1-\delta} - c\right]} \end{cases},$$

where $\Delta_F(b, a) \equiv F(b) - F(a)$ with $a \leq b$.

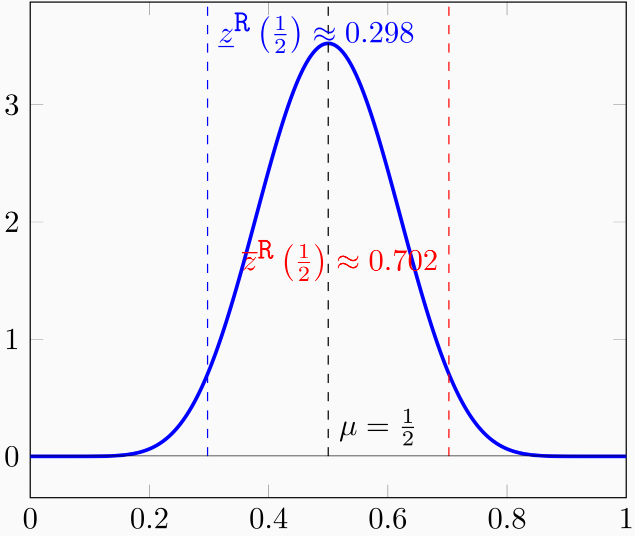
Proposition on the Symmetric Case

Proposition (continued)

- The maximum and minimum of M^{R} are, respectively, given as part of the solution to a system of three equations composed of each of the following equations and two equations in (1) with $\mu = \overline{\mu}^{\mathrm{R}}$ or $\mu = \underline{\mu}^{\mathrm{R}}$.

$$\begin{aligned}
\overline{\mu}^{\mathrm{R}} &= \frac{1}{2} + \delta \frac{2-\pi}{1-\delta}\left(\int_0^{\underline{z}^{\mathrm{R}}(\overline{\mu}^{\mathrm{R}})} \frac{1}{2} - z \mathrm{d}F(z) + \int_{\overline{z}^{\mathrm{R}}(\overline{\mu}^{\mathrm{R}})}^{1} \frac{1}{2} - z \mathrm{d}F(z)\right) \\
&\quad + c\left(\int_0^{\underline{z}^{\mathrm{R}}(\overline{\mu}^{\mathrm{R}})} z \mathrm{d}F(z) + \int_{\overline{z}^{\mathrm{R}}(\overline{\mu}^{\mathrm{R}})}^{1} z \mathrm{d}F(z) + \frac{1-\delta}{\delta\pi}\right) \quad \textit{and} \\
\underline{\mu}^{\mathrm{R}} &= \frac{1}{2} + \delta \frac{2-\pi}{1-\delta}\left(\int_0^{\underline{z}^{\mathrm{R}}(\underline{\mu}^{\mathrm{R}})} \frac{1}{2} - z \mathrm{d}F(z) + \int_{\overline{z}^{\mathrm{R}}(\underline{\mu}^{\mathrm{R}})}^{1} \frac{1}{2} - z \mathrm{d}F(z)\right) \\
&\quad - c\left(\int_0^{\underline{z}^{\mathrm{R}}(\underline{\mu}^{\mathrm{R}})} 1 - z \mathrm{d}F(z) + \int_{\overline{z}^{\mathrm{R}}(\underline{\mu}^{\mathrm{R}})}^{1} 1 - z \mathrm{d}F(z) + \frac{1-\delta}{\delta\pi}\right).
\end{aligned}$$

Example: Symmetric Case



Proposition on the Asymmetric Case

Proposition

Consider the union of two half-open intervals $M^{\mathtt{E}} \equiv \left[0, \underline{\mu}^{\mathtt{E}}\right) \cup \left(\overline{\mu}^{\mathtt{E}}, 1\right]$, where the thresholds $\underline{\mu}^{\mathtt{E}}$ and $\overline{\mu}^{\mathtt{E}}$ are defined below. When $\mu \in M^{\mathtt{E}}$, the strategies described in the figure constitute an MPE.

- In no-disaster periods, Player 1 attacks Player 2 when $\mu < \underline{\mu}^{\mathtt{E}}$ and Player 2 attacks Player when $\mu > \overline{\mu}^{\mathtt{E}}$.

Proposition on the Asymmetric Case

Proposition (continued)

- Given $\mu \in M^{\mathrm{E}}$, the thresholds $\overline{z}^{\mathrm{E}(\mu)}$ and $\underline{z}^{\mathrm{E}(\mu)}$ are given as the solution to the following system of equations.

$$
\begin{cases}
\overline{z}^{\mathrm{E}}(\mu) = & \delta \cdot \dfrac{\begin{bmatrix} (1-\pi)\left[\dfrac{1-\delta\pi/2}{1-\delta} - c\right] + \\ \pi\left(\mu + \left(\displaystyle\int_0^{\underline{z}^{\mathrm{E}}(\mu)} z\mathrm{d}F(z) + \int_{\overline{z}^{\mathrm{E}}(\mu)}^1 z\mathrm{d}F(z)\right)\left[\delta\dfrac{2-\pi}{1-\delta} - c\right]\right)\end{bmatrix}}{\left(1-\delta\pi\Delta_F\left(\overline{z}^{\mathrm{E}}(\mu), \underline{z}^{\mathrm{E}}(\mu)\right)\right)\left[\delta\dfrac{2-\pi}{1-\delta} - c\right]} \\
\underline{z}^{\mathrm{E}}(\mu) = & 1 - \delta \cdot \dfrac{\begin{bmatrix} (1-\pi)\left[\dfrac{1-\delta\pi/2}{1-\delta} - c\right] + \\ \pi\left(1-\mu + \begin{bmatrix} 1-\Delta_F\left(\overline{z}^{\mathrm{E}}(\mu), \underline{z}^{\mathrm{E}}(\mu)\right) \\ -\left(\displaystyle\int_0^{\underline{z}^{\mathrm{E}}(\mu)} z\mathrm{d}F(z) + \int_{\overline{z}^{\mathrm{E}}(\mu)}^1 z\mathrm{d}F(z)\right)\end{bmatrix}\left[\delta\dfrac{2-\pi}{1-\delta} - c\right]\right)\end{bmatrix}}{\left(1-\delta\pi\Delta_F\left(\overline{z}^{\mathrm{E}}(\mu), \underline{z}^{\mathrm{E}}(\mu)\right)\right)\left[\delta\dfrac{2-\pi}{1-\delta} - c\right]}.
\end{cases}
\tag{2}
$$

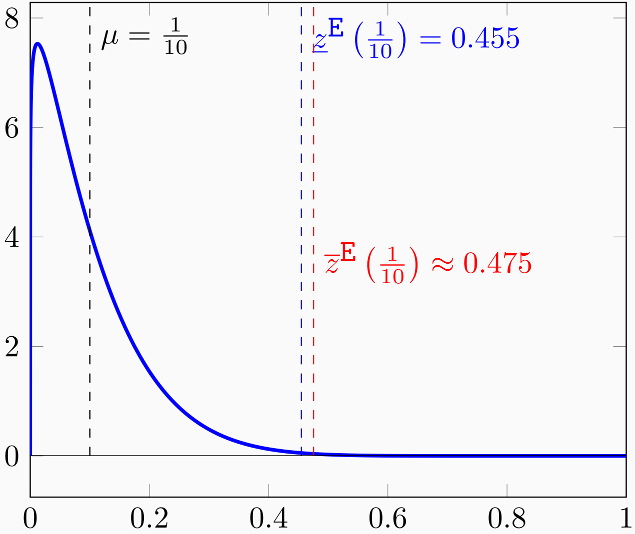
Proposition on the Asymmetric Case

Proposition (continued)

- The values of $\overline{\mu}^{\mathtt{E}}$ and $\overline{\mu}^{\mathtt{E}}$ are, respectively, given as part of the solution to the system of three equations composed of each of the following equations and two equations in 2 with $\mu = \overline{\mu}^{\mathtt{E}}$ or $\mu = \underline{\mu}^{\mathtt{E}}$.

$$
\begin{aligned}
\overline{\mu}^{\mathtt{E}} \quad &= \quad \frac{1}{2} + \delta\frac{2-\pi}{1-\delta}\left(\int_0^{\underline{z}^{\mathtt{E}}\left(\overline{\mu}^{\mathtt{E}}\right)} \frac{1}{2} - z\mathrm{d}F(z) + \int_{\overline{z}^{\mathtt{E}}\left(\overline{\mu}^{\mathtt{E}}\right)}^{1} \frac{1}{2} - z\mathrm{d}F(z)\right) \\
&\quad + c\left(\int_0^{\underline{z}^{\mathtt{E}}\left(\overline{\mu}^{\mathtt{E}}\right)} z\mathrm{d}F(z) + \int_{\overline{z}^{\mathtt{E}}\left(\overline{\mu}^{\mathtt{E}}\right)}^{1} z\mathrm{d}F(z) + \frac{1-\delta}{\delta\pi}\right) \\
\underline{\mu}^{\mathtt{E}} \quad &= \quad \frac{1}{2} + \delta\frac{2-\pi}{1-\delta}\left(\int_0^{\underline{z}^{\mathtt{E}}\left(\underline{\mu}^{\mathtt{E}}\right)} \frac{1}{2} - z\mathrm{d}F(z) + \int_{\overline{z}^{\mathtt{E}}\left(\underline{\mu}^{\mathtt{E}}\right)}^{1} \frac{1}{2} - z\mathrm{d}F(z)\right) \\
&\quad - c\left(\int_0^{\underline{z}^{\mathtt{E}}\left(\underline{\mu}^{\mathtt{E}}\right)} 1 - z\mathrm{d}F(z) + \int_{\overline{z}^{\mathtt{E}}\left(\underline{\mu}^{\mathtt{E}}\right)}^{1} 1 - z\mathrm{d}F(z) + \frac{1-\delta}{\delta\pi}\right).
\end{aligned}
$$

Example: Asymmetric Case



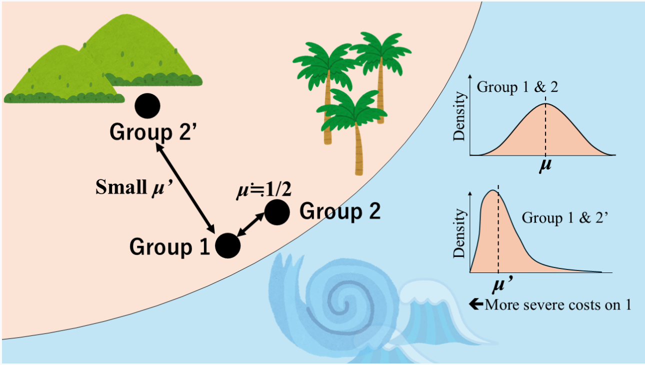
Empirical Implication of the Theoretical Model

Expressing the Model in Terms of Data

- Next section: "What do we learn **if** the model makes sense?"
- Before that, interested in: "Does the model explain data?"
  - Suggestive evidence on droughts in Africa

Expressing the Model in Terms of Data

- Connecting theory to data
- Key parameter μ: **Dyadic** nature
  - Need to use geo-referenced data



Expressing the Model in Terms of Data

- Data
  - Conflict: Armed Conflict Location and Event Data (ACLED)
    - Unit of observation: Event of pol. violence in Africa
    - **1997**-
  - Disaster: Palmer Drought Severity Index (PDSI)
    - Monthly score for $2.5^{\circ} \times 2.5^{\circ}$ grid
    - Score: -10 (dry) to $+10$ (wet)
    - 1850-**2018**

Expressing the Model in Terms of Data

- Recall Corollary 1
  - To define empirical analogues, we need three things

$$(i)\quad \Pr\left(\overbrace{Y_t^{\texttt{game}} = 1}^{(1)} \middle| \overbrace{D_t = 1,}^{(2)} \overbrace{\mu^{\texttt{R}}}^{(3)}\right) > \Pr\left(Y_t^{\texttt{game}} = 1 \middle| D_t = 0, \mu^{\texttt{R}}\right)$$

$$(ii)\quad \Pr\left(Y_t^{\texttt{game}} = 1 \middle| D_t = 1, \mu^{\texttt{E}}\right) < \Pr\left(Y_t^{\texttt{game}} = 1 \middle| D_t = 0, \mu^{\texttt{E}}\right)$$

(1) Conflict in equilibrium
(2) Disaster
(3) Level of asymmetry in disaster risks

Expressing the Model in Terms of Data

	Model	Empirical analogue	Note
Conflict	$Y_t^{\texttt{game}}$	$Y_{dt}^{\texttt{data}} = 1$	1 in ACLED
Disaster	D_t	$\texttt{PDSI}_{d,t-1} \in [-10, 10]$	Smaller = drought
Asymmetry	μ	$\texttt{gov}_{dt} \in \{0, 1\}$	Random variable

(1) $Y_t^{\texttt{game}}$: Conflict in equilibrium

- ACLED: Event-level data with location, time & involved parties
- Define the presence of conf. in dyad d at time t as:

$$Y_{dt}^{\texttt{data}} = 1$$

- Binary in theory, but 1 in ACLED (data on conf. events)

Expressing the Model in Terms of Data

	Model	Empirical analogue	Note
Conflict	$Y_t^{\mathtt{game}}$	$Y_{dt}^{\mathtt{data}} = 1$	1 in ACLED
Disaster	D_t	$\mathtt{PDSI}_{d,t-1} \in [-10, 10]$	Smaller = drought
Asymmetry	μ	$\mathtt{gov}_{dt} \in \{0, 1\}$	Random variable

(2) D_t: Disaster at time t

- Use PDSI of the previous month

$$\mathtt{PDSI}_{d,t-1} \in [-10, 10]$$

- Binary in the model, but continuous here
    - Smaller PDSI = Drought ($D_t = 1$)

Expressing the Model in Terms of Data

	Model	Empirical analogue	Note
Conflict	$Y_t^{\texttt{game}}$	$Y_{dt}^{\texttt{data}} = 1$	1 in ACLED
Disaster	D_t	$\texttt{PDSI}_{d,t-1} \in [-10, 10]$	Smaller = drought
Asymmetry	μ	$\texttt{gov}_{dt} \in \{0, 1\}$	Random variable

(3) μ: Level of asymmetry in disaster risks

- Assume: gov. forces tend to be more resilient than rebels
- Define the asymmetry in disaster risks for dyad d at time t as:

$$\texttt{gov}_{dt} \equiv \mathbb{1}\left\{\begin{array}{l}\text{One of the belligerents in an incident} \\ \text{in dyad } d \text{ at time } t \text{ is state forces}\end{array}\right\}$$

- $\texttt{gov}_{dt} = 1 \Longrightarrow$ Asymmetric dyad
- $\texttt{gov}_{dt} = 0 \Longrightarrow$ Symmetric dyad

Prediction and Results

- Again, the Corollary drawn from the model:

$$
\begin{aligned}
(i)\quad & \Pr\left(Y_t^{\texttt{game}} = 1 \middle| D_t = 1, \mu^{\texttt{R}}\right) > \Pr\left(Y_t^{\texttt{game}} = 1 \middle| D_t = 0, \mu^{\texttt{R}}\right) \\
(ii)\quad & \Pr\left(Y_t^{\texttt{game}} = 1 \middle| D_t = 1, \mu^{\texttt{E}}\right) < \Pr\left(Y_t^{\texttt{game}} = 1 \middle| D_t = 0, \mu^{\texttt{E}}\right)
\end{aligned}
$$

- Recall $Y_{dt}^{\texttt{data}} = 1$ in ACLED data
  - Unable to compare cases of 1 and 0 directly
- How can we assess the theory without $Y_{dt}^{\texttt{data}} = 0$?

Prediction and Results

- Focus on Part (ii)
  - Reinterpret parameter μ as a random variable, $\mu^{\mathtt{RV}} \in [0,1]$

Corollary 2

- Let $\Pr\left(\mu^{\mathtt{RV}} \in M^{\mathtt{E}}\right) \in (0,1)$. Then

$$\begin{aligned} &\overbrace{\Pr\left(\overbrace{\mu^{\mathtt{RV}} \in M^{\mathtt{E}}}^{\text{Asymmetric case}} \middle| Y_t^{\mathtt{game}} = 1, D_t = 0\right)}^{=1} \\ > \quad &\Pr\left(\mu^{\mathtt{RV}} \in M^{\mathtt{E}} \middle| Y_t^{\mathtt{game}} = 1, D_t = 1\right) \end{aligned}$$

- Recall: in eq., conflict occurs when $D_t = 0$ only in aym. cases
  - Thus the result just says:
    "Suppose conflict occurred when $D_t = 0$. Then it must be between groups with asymmetric disaster risks"

Prediction and Results

- Use the empirical analogues to the theory:

Implication

$$\Pr\left(\underbrace{\texttt{gov}_{dt}=1}_{\text{Stands for } \mu^{\mathrm{RV}} \in M^{\mathrm{E}}} \middle| \overbrace{Y_{dt}^{\texttt{data}}=1}^{\text{Fixed }=1\text{ in data}},\ \underbrace{\text{High }\texttt{PDSI}_{d,t-1}}_{\text{Stands for } D_t=0}\right)$$

$$> \quad \Pr\left(\texttt{gov}_{dt}=1 \middle| Y_{dt}^{\texttt{data}}=1, \underbrace{\text{Low }\texttt{PDSI}_{d,t-1}}_{\text{Stands for } D_t=1}\right)$$

- New prediction
    - But not a causal claim

Prediction and Results

- To assess the implication, consider

$$
\begin{aligned}
& \Pr\left(\mathtt{gov}_{dt} = 1 \middle| Y_{dt}^{\mathtt{data}} = 1, \mathtt{PDSI}_{dt}\right) \\
= \quad & \frac{\exp\left(\tilde{\beta}_0 + \beta_1 \mathtt{PDSI}_{dt} + \beta_2 Y_{dt}^{\mathtt{data}}\right)}{1 + \exp\left(\tilde{\beta}_0 + \beta_1 \mathtt{PDSI}_{dt} + \beta_2 Y_{dt}^{\mathtt{data}}\right)} \\
= \quad & \frac{\exp\left(\beta_0 + \beta_1 \mathtt{PDSI}_{dt}\right)}{1 + \exp\left(\beta_0 + \beta_1 \mathtt{PDSI}_{dt}\right)}
\end{aligned}
$$

- Model prediction: Increasing func. of $\mathtt{PDSI}_{d,t-1}$
    - Estimand: Pair of constant & coefficient (β_0, β_1)

Prediction and Results

	Dependent variable: gov_{dt}			
	(1)	(2)	(3)	(4)
$\texttt{PDSI}_{d,t-1}$	**0.034*****	**0.033*****		**0.029*****
	(0.004)	(0.004)		(0.005)
Distance to capital		0.053***		0.053***
(standardized)		(0.010)		(0.010)
$\texttt{PDSI}_{dt}$			0.025***	0.008
			(0.004)	(0.005)
Constant	0.758***	0.759***	0.754***	0.760***
	(0.011)	(0.011)	(0.010)	(0.011)
Observations	43,194	43,194	43,194	43,194

Note: $^{\dagger}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$