Networks in Conflict: Theory and Evidence from the Great War of Africa

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Motivation

- Pacification is a complex question. Many wars involve multiple actors with intricate webs of alliances and rivalries:
  - $\longrightarrow$ Recent civil wars: Somalia, Syria, Uganda, Democratic Republic of Congo, ...
  - $\longrightarrow$ In history: Peloponnesian War, Caesar's Wars in Gaul, Thirty Years' War, Napoleonic Wars, WWI, WWII ...
- Imperfect theoretical guidance: Most existing theories focus on two player/coalition wars...
  - $\longrightarrow$ yet, this is rare in the real world;
  - $\longrightarrow$ alliances are often non-unified coalitions; comitment issues among allied groups who retain independent agendas

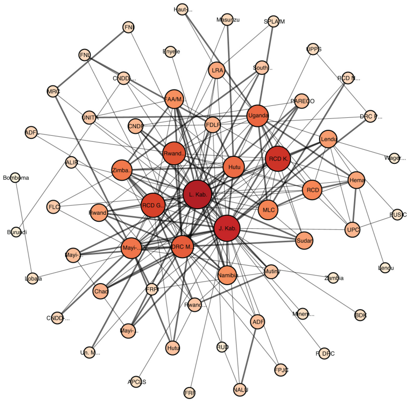
Quantitative Guide for Intervention: A first Attempt

- How does the network of military alliances and rivalries affect overall conflict intensity, destruction and death toll?
  → Quantitative analysis as a guide for pacification policy
- We combine network theory with standard non-cooperative conflict theory tools (i.e. contest success function)
  → We postulate that each group's operational performance hinges on two externalities with opposite signs: the fighting effort of its allies and that of its enemies.
  → Due to externalities, pacifying a group affects the actions of all the other groups in a complex way
  → Network structure reveals which actors are the most critical for the escalation/containment of violence

Empirical Application - I

- Democratic Republic of Congo - 1998-2010.
  Natural setting: 80 fighting groups; rich network of alliances/enmities
- We perform a structural estimation based on the (Nash) equilibrium conditions
  1. estimate the fighting externalities;
  2. perform counterfactual pacification policies

Network of alliances & enmities in DRC



Empirical Application - II

- Quantitative evaluation of interventions that change the nature of network links; e.g., bringing peace to traditional ethnic rivalries. Which links is it best to pacify?
- The most destructive groups are not necessarily the most active, but rather the most influential ones through their alliance/enmity links (multiplier effects)
- In most of the paper we treat the network as exogenous.

  → Yet, policy interventions may reshuffle alliances.

  → We use a multinomial logit (random utility) model to predict the probability that each link changes nature after policy intervention (e.g., an alliance breaks down).

Literature

- Generally linked to the literature on the economics of networks (cf. e.g. Jackson and Zenou 2014; Acemoglu and Ozdaglar 2011; Jackson 2008).
- Most previous work on conflict networks is theoretical.
  - Franke and Öztürk (2009): agents choose their fighting efforts to attack their neighbors. No alliances.
    Focus on (low scale) specific networks.
  - Hiller (2012): a model of network formation where having more "friends" makes a player "stronger"
- Empirics: Acemoglu, Garcia-Jimeno and Robinson (2014) estimate a structural politico-economic model of public good provision using a network of Colombian municipalities.
- Key player analysis: Ballester et al. (2006), Liu *et al.* (2011), Lindquist and Zenou (2013). Focus is not on civil conflicts.

Network

- One period model.
- Exogenous network G of Groups $i \in \mathcal{N} = \{1, \ldots, n\}$ with *signed* adjacency matrix $\mathbf{A} \equiv \mathbf{A}^{+} - \mathbf{A}^{-}$

$$a_{ij} \equiv a_{ij}^{+} - a_{ij}^{-} = \begin{cases} 1, & \text{if } i \text{ and } j \text{ are allied} \\ -1, & \text{if } i \text{ and } j \text{ are enemies} \\ 0, & \text{if relationship } (i,j) \text{ is neutral.} \end{cases}$$

- We assume:
  1. $a_{ij} = a_{ji}$ (reciprocity of alliance & enmity)
  2. alliance and enmity are mutually exclusive
- We do not require structural balance.

Augmented Contest Success Function

- Pay-off (utility) function:
  standard ratio-form (Tullock) contest success function

$$\pi_i = \frac{\varphi_i}{\sum_{j=1}^{n} \varphi_j} \times \underbrace{V}_{\text{Territory}} - \underbrace{x_i}_{\text{fighting effort}}$$

- Generalization of the CSF:
  Group i's operational performance, φ_i, depends on its own fighting effort, x_i, and on that of its allies and enemies:

$$\varphi_i\left(x_i, x_{-i}, \mathbf{A}\right) = x_i + \left[\beta \sum_{j=1}^{n} a_{ij}^{+} x_j - \gamma \sum_{j=1}^{n} a_{ij}^{-} x_j\right] + \underbrace{\mathbf{Z}_{it}\delta + e_i + \varepsilon_{it}}_{\text{Shifters}}$$

- Structural shifters $(\mathbf{Z}_{it}, e_i + \varepsilon_{it})$ are resp. observed and unobserved (by the econometrician): group size, scale of operation, foreign affiliations, climatic shocks, weaponry efficiency, leadership.

Discussion

1. Even allied groups compete one with another over V. Alliances are no "unitary" coalitions.

   $\longrightarrow$ Rebel forces in Syria today (Al Nusra front, Daesh, Syrian National Council, Peshmerga...).

2. The externalities through the fighting strength, ϕ_i, compound with those already present in the CSF.

3. Not over-parametrized model.

Equilibrium

- First Order conditions

$$\frac{\partial \pi_i (G, \mathbf{x})}{\partial x_i} = 0 \Longleftrightarrow \varphi_i = \frac{1}{1 + \beta d_i^+ - \gamma d_i^-} \left(1 - \frac{1}{V} \sum_{j=1}^{n} \varphi_j \right) \sum_{j=1}^{n} \varphi_j .$$

- Rearranging terms yields the equilibrium OP

$$\varphi_i^* (G) = \Lambda (G) (1 - \Lambda (G)) \Gamma_i (G) \times V,$$

where

$$\Gamma_i (G) \equiv \frac{1}{1 + \beta d_i^+ - \gamma d_i^-}, \text{ and } \Lambda (G) \equiv 1 - \frac{1}{\sum_{i=1}^{n} \Gamma_i (G)}.$$

- $\varphi_i^* (G)$ is not affected by the shifters. Only network topology matters. Key for identification.

Structural Equation

- The result above allows us to characterize equilibrium as a simple linear closed-form expression

$$x^*_{i,t} = -\beta \sum_j a^+_{ij} x^*_{j,t} + \gamma \sum_j a^-_{ij} x^*_{j,t} - \mathbf{Z}_{it}\delta + \underbrace{\varphi^*_i(G)}_{\text{Network Feedback}} - e_i - \varepsilon_{it}$$

- Interpretation
  Contest effect (enemies) and free-riding effect (allies)
- This system of equations will be estimated to obtain $(\hat{\beta}, \hat{\gamma})$

Welfare

- Aggregate Welfare:

$$\mathcal{W} \equiv \sum_{i=1}^{n} \pi_i = V - \mathcal{D}$$

where $\mathcal{D} \equiv \sum_{i=1}^{n} x_i$ represents rent dissipation, (e.g. cost of mobilizing troops, casualties, damages...)

- The rent dissipation hinges on the network structure.
We can study policies to minimize $\mathcal{D}$, e.g., wiping out groups, pacification policies, weapon embargo...

Two Key Properties of the Equilibrium

1. Centrality determines fighting effort
   In our contest game two (Bonacich) centrality measures gauge the network multiplier effect attached respectively to rivalries or alliances.
2. Many friendships (enmities) scale down (up) conflict and rent dissipation

Two simple networks (regular and line graph) provide intuition for those properties

Theoretical Example - Regular Graph

- A *regular graph*, is a symmetric graph where each group has d^+ allied and d^- rivals

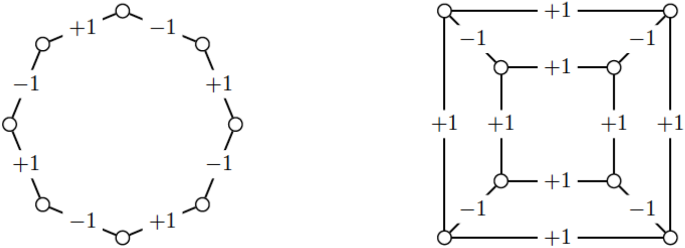


Figure: The figure shows two examples for regular graphs.

- Simple closed-form characterization of the Nash Equilibrium

Example - Regular Graph

- The (symmetric) solution yields:

$$x_i^* = x^* = \frac{n - (1 + \beta d^+ - \gamma d^-)}{n(1 + \beta d^+ - \gamma d^-)} \times \frac{V}{n}$$

$$\pi_i^* = \pi^* = \left(\frac{1}{n} + \frac{\beta d^+ - \gamma d^-}{1 + \beta d^+ - \gamma d^-} \right) \times \frac{V}{n}$$

- Two special cases of interest:

1. "Harmonious society" [Rousseau]: $d^+ = n - 1$ and $\beta \to 1$
$\Rightarrow x^* = 0$ and $\pi^* = V/n$. No rent dissipation!
2. "Homo homini lupus" [Hobbes]:
$d^- = n - 1$ and $\gamma \to 1/\left(n^2 - 1\right)$
$\Rightarrow x^* \to V/n$ and $\pi^* \to 0$. Full rent dissipation!

- The model spans outcomes from failed states to peaceful sharing without any rent dissipation.

Context of DRC conflict

- We study the Second Congo War ("Great African War"), 1998-2010 (after the end of the 1996-97 conflict).
- Although the war is officially over in 2003, fighting continues till today on a large scale.
- The deadliest conflict since WWII, with 3-to-5 million excess deaths (Olsson and Fors, 2004; Autesserre, 2008).
- An emblematic conflict for the involvement of many inter-connected domestic and foreign actors: "Three Congolese rebel armies, 14 foreign armed groups, and countless militias" (Autesserre, 2008).

Empirical Strategy (overview)

- Assume a time-invariant network (later, relaxed).
- A repetition of static conflicts.
- Violence changes over time driven by exogenous shocks.
- Steps of analysis
  - $\longrightarrow$ panel IV estimate of structural parameters β and δ
  - $\longrightarrow$ policy counterfactuals (remove some groups, pacification policies, etc.).
- Extensions:
  - $\longrightarrow$ time-varying network.
  - $\longrightarrow$ ethnic/spatial instruments for network links
  - $\longrightarrow$ network recomposition after policy shocks.

Mapping the Model into Observables

-
  1. Network links
     → expert coding, observed behavior in battlefields
  2. Fighting effort
     → extent to which each group is involved in fighting
  3. Exogenous shocks
     → rainfall variation across times and regions of DRC

Measuring Fighting Effort

- ACLED contains 4765 violent events in the DRC
  - → For each event, information over location, date and actors involved on the two opposing sides.
- We construct a time-varying (non-bilateral) measure of fighting effort:
  $x_{it} \equiv$ yearly number of violent events involving group i.
  → Extension: only # of battles
- Panel of fighting effort of 80 armed groups over 1998-2010.

Network of Alliances&Enmities in DRC

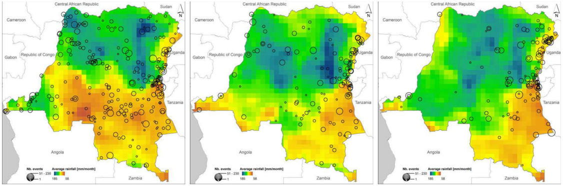
Coding of Alliances and Enmities

- We use hierarchically:
  1. Expert coding (Stockholm International Peace Research Institute, Cunningham *et al.* 2013, International Crisis Group (NGO), Williams 2013)
  2. Bilateral information from ACLED
     → We code as allied two groups which fought together at some point and never fought on opposing sides;
     → We code as enemies two groups that are recorded fighting on opposite sides at least twice and never on the same side.
     → Otherwise, neutrals
- # of problematic dyads boil down to 4
- We do robustness analysis...

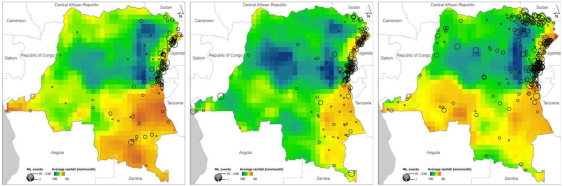
Weather Shocks

- Play a key role in identification:
  $\longrightarrow$ rainfall increases the opportunity cost of fighting (Miguel et al. 2004, Jia 2014, etc.).
- Geolocalized rainfall measures (grid of 0.5 x 0.5 degree^2 cell).
- Source: GPCC (gauge-based)
  $\longrightarrow$ we compare it with satellite measures

Geolocalized Violence in DRC



(a) 1998-1999 (b) 2000-2001 (c) 2002-2003



(d) 2004-2005 (e) 2006-2007 (f) 2008-2010

Panel Estimation

- Panel dataset on 80 armed groups over 1998-2010

$$x_{i,t}^{*} = -\beta \sum_{j} a_{ij}^{+} x_{j,t}^{*} + \gamma \sum_{j} a_{ij}^{-} x_{j,t}^{*} - \mathbf{Z}_{it}\delta + \underbrace{\varphi_i^{*}(G)}_{\text{Network Feedback}} - e_i - \varepsilon_{it}$$

- Time-invariant unobserved heterogeneity $\varphi_i^{*}(G) - e_i$
  $\rightarrow$ Panel allows for group FE
  $\rightarrow$ Robustness: Time-varying network $\varphi_i^{*}(G_t)$ is estimated with an iterative procedure.
- Time dummies interacted with group characteristics (e.g., state armies, foreign groups, large groups, etc.)

Identification I

$$x^*_{i,t} = -\beta \sum_j a^+_{ij} x^*_{j,t} + \gamma \sum_j a^-_{ij} x^*_{j,t} - \mathbf{Z}_{it}\delta + \underbrace{\varphi^*_i(G)}_{\text{Network Feedback}} - e_i - \varepsilon_{it}$$

- Endogeneity bias
  - → group i's effort depends on group j's effort, but j's effort is in turn affected by i's effort
  - → OLS yields inconsistent estimates
- IV strategy similar to that in Acemoglu, Garcia-Jimeno and Robinson (2014) who study local state capacity in a network of Colombian municipalities
- Crux: exploit the variation in exogenous shifters (**Z**)

Identification II

$$x_{i,t}^{*} = -\beta \sum_{j} a_{ij}^{+} x_{j,t}^{*} + \gamma \sum_{j} a_{ij}^{-} x_{j,t}^{*} - \mathbf{Z}_{it}\delta + \mathbf{FE}_{i} - \varepsilon_{it}$$

- We use $\sum_j a_{ij}^{+}\mathbf{Z}_{jt}$ and $\sum_j a_{ij}^{-}\mathbf{Z}_{jt}$ as excluded instruments (consistent with our structural equation)
  - $\longrightarrow$ $\mathbf{Z}_{jt}$: time-varying climatic shocks (rainfall) impacting fighting group "homelands". Rationale: rain shocks affect income and military efficiency
  - $\longrightarrow$ The instruments are the weather conditions at t in the homeland of group i's friends and in that of its enemies
  - $\longrightarrow$ Note: in the second-stage we control for weather conditions in *i*'s own homeland

Baseline results (second stage)

Table 1: Benchmark Second Stage

	Dependent variable: Total Fighting					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	Reduced IV	Full IV	Neutrals	Battles	d->=1 & d+>=1
Tot. Fight. Enemies (TFE)	0.07***	0.13**	0.07***	0.08***	0.08***	0.09***
	(0.02)	(0.06)	(0.02)	(0.02)	(0.02)	(0.02)
Tot. Fight Allies (TFA)	0.00	-0.22**	-0.12***	-0.11***	-0.12***	-0.16***
	(0.02)	(0.09)	(0.04)	(0.03)	(0.04)	(0.06)
Total Fight. of Neutrals (TFN)				0.00	0.00	0.01
				(0.00)	(0.00)	(0.01)
Additional controls	Reduced	Reduced	Full	Full	Full	Full
Estimator	OLS	IV	IV	IV	IV	IV
Set of Instrument Variables	n.a.	Restricted	Full	Full	Full	Full
Observations	1040	1040	1040	1040	988	598
Kleibergen-Papp F-stat	n.a.	10.6	19.5	22.5	20.6	17.8
SOC	No	Yes	Yes	Yes	Yes	Yes

Notes: An observation is a given armed group in a given year. The panel contains 80 armed groups between 1998 and 2010. All regressions include group fixed effects and control for rainfall in the own group's territory. Columns 1-3 include time fixed effects. Robust standard errors corrected for Spatial HAC in parentheses. Significance levels are indicated by * p<0.1, ** p<0.05, *** p<0.01.

Baseline results (first stage)

Table 2 : Baseline First Stage

	IV regression of column (2)		IV regression of column (3)		IV regression of column (4)	
Dep. Variable:	TFE	TFA	TFE	TFA	TFE	TFA
	(1)	(2)	(3)	(4)	(5)	(6)
Rain (t-1) Enemies	**-1.60*** **	-0.02	**-1.35*** **	0.28*	**-1.33*** **	0.29**
	(0.30)	(0.14)	**(0.33)**	(0.16)	**(0.32)**	(0.14)
Sq. Rain (t-1) Ene.	0.00***	0.00	0.00***	-0.00	0.00***	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Rain (t-1) Allies	0.13	**-0.93*** **	0.03	**-0.59*** **	0.09	**-0.57** **
	(0.28)	**(0.16)**	(0.22)	**(0.19)**	(0.22)	**(0.23)**
Sq. Rain (t-1) Alli.	-0.00	0.00***	-0.00	0.00***	-0.00	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Current Rain Enemies			**-1.12*** **	0.13	**-0.94*** **	0.07
			(0.24)	(0.10)	**(0.26)**	(0.11)
Sq. Curr. Rain Ene.			0.00***	-0.00***	0.00*	-0.00**
			(0.00)	(0.00)	(0.00)	(0.00)
Current Rain Allies			-0.46**	**-0.37*** **	-0.41**	**-0.45*** **
			(0.20)	**(0.12)**	(0.21)	**(0.16)**
Sq. Curr. Rain Alli.			0.00	0.00***	0.00	0.00***
			(0.00)	(0.00)	(0.00)	(0.00)
Hansen J (p-value)						
Observations	1040	1040	1040	1040	1040	1040

Notes: An observation is a given armed group in a given year. The panel contains 80 armed groups between 1998 and 2010. All regressions include group fixed effects and control for rainfall in the own group's territory. Columns 1-4 contain time fixed effects. Robust standard errors corrected for Spatial HAC in parentheses. Significance levels are indicated by * p<0.1, ** p<0.05, *** p<0.01.

Quantitative Effects

- Partial Equilibrium Approach
  - → A one s.d. increase in total fighting of the enemies (92 events) increases fighting by 0.4 s.d. (8 events)
  - → A one s.d. increase in total fighting of the allies (75 events) decreases fighting by 0.4 s.d. (7.5 events)
- General Equilibrium Approach
  - → Switching all Enmity Links to Neutrality reduces violence by 65 percent
  - → Switching all Alliance Links to Neutrality increases violence by 90 percent

Robustness checks

1. Using only IVs of degree two (e.g., rain fall of enemies' enemies, enemies' friends,...)
2. Using the (non-overlapping) historical homelands of the affiliated ethnic group from Murdock (1959) to compute the rain fall measure for each given group
3. Alternative coding rules or sources for network links; Merging groups; Non classical measurement error in rainfall.(comparing ground data to Satellite data).
4. Sample split. 1998-2001 subperiod for coding the network, and 2002-2010 subperiod for model estimation.
5. Control for lagged fighting efforts of allies/enemies (zero coefficient)
6. TOBIT estimators (to account for zeroes in fighting)
7. Mismeasurement of links (attenuation or expansion bias). Monte Carlo approach: we rewire links in the observed network at random, and measure the robustness of our estimates in such perturbed networks

Exogenous Network Changes

- Many local sub-conflicts (North Kivu, South Kivu, Uganda-Rwanda, Ituri, LRA-Uganda, Angola MPLA-UNITA, various local rebellions)
- Not all subconflicts are hot at the same time. Many groups are only active in subperiods.
- Baseline: include Group FE $\times$ Inactivity Dummy
- Alternative: Unbalanced sample with an exogenous time-varying network (Iterated Least Square procedure)

$$x_{i,t}^* = -\beta \sum_j a_{ij}^+ x_{j,t}^* + \gamma \sum_j a_{ij}^- x_{j,t}^* - \underbrace{\mathbf{Z}_{it}\delta}_{\text{OBS.}} + \underbrace{+\frac{\Lambda^{\beta,\gamma}(G_t)\left(1-\Lambda^{\beta,\gamma}(G_t)\right)V}{1+\beta d_{i,t}^+ - \gamma d_{i,t}^-}}_{\text{TIME-VAR. NETWORK}} - \underbrace{e_i}_{\text{FE}} - \varepsilon_{it}$$

Counterfactual Experiments

- We can quantify the effect of pacification policies (i.e. a change in the network structure $\mathbf{A}^+, \mathbf{A}^-$).
- Based on the point estimates of β and γ, we simulate counterfactual equilibria with the reduced form of the model.

$$\mathbf{x} = (\mathbf{I} + \hat{\beta}\mathbf{A}^+ - \hat{\gamma}\mathbf{A}^-)^{-1}\left[\hat{\Lambda}(1 - \hat{\Lambda})\Gamma - (\mathbf{Z}\widehat{\boldsymbol{\alpha}} + \widehat{\mathbf{e}} + \boldsymbol{\epsilon})\right]$$

Removing Groups

Multipliers

- Removing some groups has a large *multipliers*; others have small effects
  - → RCDs 1.7, Rwandan Army 1.4, LRA 1.4, MayiMayi Mil. 0.5
  - → one group has a negative multiplier
- Removing multiple players:
  - → Uganda, Rwanda & ass.: -45%;
  - → all Hutu groups: -8%;
  - → all actors from Ituri conflict -9%;
  - → all foreign groups: -28%
- Multiple key players: Rwanda&RCD-G always top 10.

Removing Groups

Key Player

Group	# Enmities	# Allies	Share fight.	$-\Delta$RD	Multipl.	$-\Delta$RD ($\pm$ 1 SD)	Multipl. ($\pm$ 1 SD)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RCD-G	14	4	0.087	0.151	1.7	[0.125, 0.181]	[1.4, 2.1]
RCD-K	13	5	0.060	0.094	1.6	[0.070, 0.151]	[1.2, 2.5]
Rwanda	17	9	0.053	0.066	1.2	[0.053, 0.109]	[1.0, 2.0]
LRA	6	1	0.041	0.056	1.4	[0.038, 0.115]	[0.9, 2.8]
FDLR	5	6	0.066	0.055	0.8	[0.059, 0.044]	[0.9, 0.7]
Mayi-Mayi	6	7	0.057	0.046	0.8	[0.054, 0.022]	[1.0, 0.4]
Uganda	13	9	0.043	0.043	1.0	[0.038, 0.048]	[0.9, 1.1]
CNDP	3	2	0.043	0.041	0.9	[0.041, 0.040]	[0.9, 0.9]
MLC	7	4	0.031	0.039	1.3	[0.026, 0.074]	[0.8, 2.4]
UPC	5	1	0.022	0.030	1.4	[0.018, 0.057]	[0.8, 2.6]
Lendu Ethnic Mil.	6	3	0.024	0.022	0.9	[0.039, -0.012]	[1.6, 0.5]
Mutiny FARDC	3	2	0.016	0.016	1.0	[0.009, 0.045]	[0.6, 2.8]
Interahamwe	7	5	0.014	0.014	1.0	[0.024, -0.017]	[1.7, 1.2]
ADF	3	4	0.013	0.012	0.9	[0.011, 0.017]	[0.8, 1.3]
FRPI	2	1	0.009	0.010	1.1	[0.003, 0.031]	[0.4, 3.7]

Pacification Policies

Switching enmities with DRC governmental Troops into neutrality

- Pacifying all rebel group with the DRC govt. forces reduces fighting by 60%
- Large multipliers (relative to bilateral fighting) for Rwanda (6), Uganda (5), RCD-G (1.9), RCD-K (1.6)
- Resolve enmities with some small players surprisingly important (e.g., Lobala Enyele Militia)
- Re-wiring Hutu-Tutsi enmities into neutral: -8.5% (small)
- Rewiring Rwanda-Uganda into a stable alliance: -10%

Pacification Policies

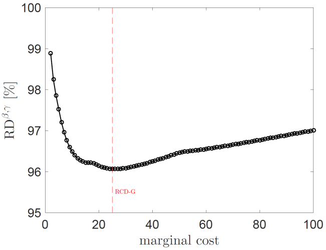
Switching enmities with DRC governmental Troops into neutrality

Set of Groups	# groups	Sh. bil. fight. FARDC	$-\Delta$RD	Multipl.	MAD	New enm. & all. (at median)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
				EXOGENOUS NETWORK		
Foreign Groups	29	0.213	0.185	0.9	–	–
Ituri	9	0.086	0.099	1.2	–	–
Out of Rwanda	6	0.062	0.014	0.2	–	–
Rwa&Uga&ass.	10	0.217	0.240	1.1	–	–
Large Groups	16	0.621	0.338	0.5	–	–

Pacification Policies

Arms Embargo : increase in the marginal cost of fighting

s	Gr. 1	Gr. 2	Gr. 3	Gr. 4	Gr. 5	Gr. 6
1-2	LRA	MLC	RCD-G	RCD-K	RWA	UPC
3	LRA	RCD-G	RCD-K	UPC		
4	LRA	RCD-G	RCD-K			
5-16	RCD-G	RCD-K				
17-49	RCD-G					
50-100	RCD-K					



Network Recomposition

Motivation

- So far, exogenous network.
- However, the network of enmities&alliances may respond to policy interventions
  - → For example, removing FDLR may lead its 7 allies (5 enemies) to form new alliances and/or reduce their enmities.
  - → How are pacification policies impacted by endogenous rewiring of the network?
- Realm of endogenous network formation.

Network Recomposition

Random Utility Model

- The unit of analysis is a dyad ij with alternatives $a \in \{-1, 0, 1\}$.
- The observed link is $a_{ij}^{obs} = \arg\max U_{ij}(a)$ where

$$
\begin{aligned}
U_{ij}(a) &= FE_i + FE_j + CSF_{ij}(a) + \\
&\quad + \mathbf{Z}_{ij}^{\top} \times \delta(\mathbf{a}) + \mathbf{X}_{ij}^{\top} \times \boldsymbol{\psi}(\mathbf{a}) + \tilde{u}_{ij}(a)
\end{aligned}
$$

$CSF_{ij}(a)$ – Joint surplus of the fighting game
$\mathbf{Z}_{ij}$ – Structural charact.: spatial distance, historical rivalries, joint ethnicity, $ij \in \{\text{Tutsi,Hutu, Foreign,Gov}\}$
$\mathbf{X}_{ij}$ – Network-related charact.: # common enemies, # common allies, # antagonistic common neighbors
$\tilde{u}_{ij}(a)$ – extreme value type I distributed shocks

Network Recomposition

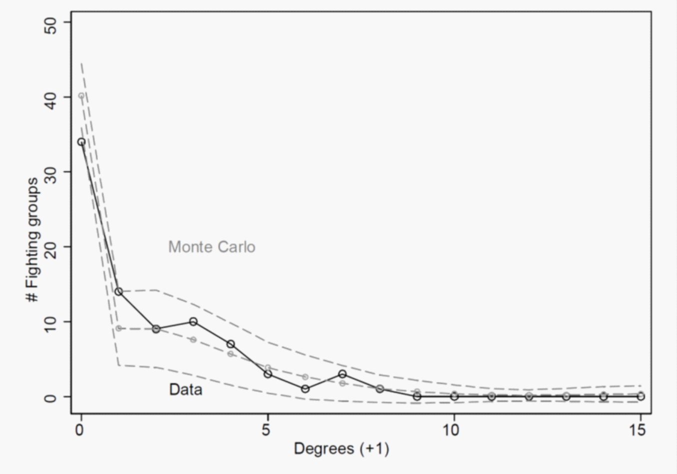
Multinomial Logit

$$U_{ij}(a) = FE_i + FE_j + CSF_{ij}(a) + \mathbf{Z}_{ij}^{\top} \times \delta(\mathbf{a}) + \mathbf{X}_{ij}^{\top} \times \boldsymbol{\psi}(\mathbf{a}) + \tilde{u}_{ij}(a)$$

- We estimate the RUM through multinomial conditional logit.
- We obtain the probability that each dyad ij is in each state, $a \in \{-1, 0, 1\}$, as a function of the RHS variables.
- The model fits well the data...

Network Recomposition

MLogit - Goodness of Fit: Degree minus distribution for 1000 pre-policy predicted networks



Network Recomposition

Redo IV Estimation using the estimated links

- Baseline analysis: Fighting effort of group i's Enemies is instrumented by $\Sigma_j d_{ij}^{-} \times RAINFALL_j$ where $d_{ij}^{-} = 1$ if and only if i and j are enemies.
- Instead, use now $\Sigma_j \pi_{ij}^{-} \times RAINFALL_j$ where π_{ij}^{-} is the predicted probability that i and j are enemies from the mLogit. $\rightarrow$ Instrument the network links d_{ij}^{-} with the structural predictors (ethnic links, geographical distance).
- Estimated coefficients are 0.12 and -0.17, both highly significant. Low F-stat (5.8).

Network Recomposition

Pacification Policies with Network Rewiring

$$U_{ij}(a) = FE_i + FE_j + CSF_{ij}(a) + \mathbf{Z}_{ij}^\top \times \delta(\mathbf{a}) + \mathbf{X}_{ij}^\top \times \boldsymbol{\psi}(\mathbf{a}) + \tilde{u}_{ij}(a)$$

- A policy change, e.g., the removal of group k

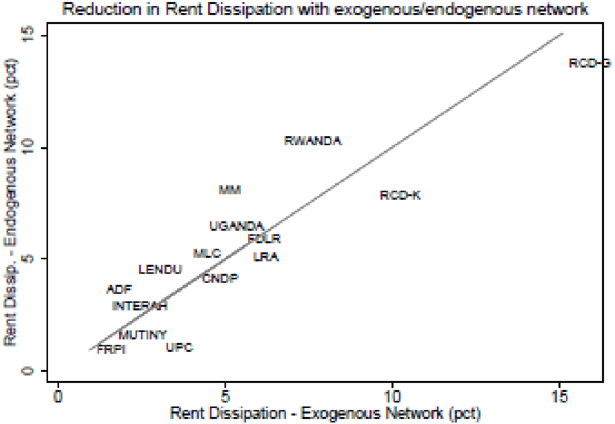
→ changes $CSF_{ij}(a)$ (for all players)
→ changes $\mathbf{X}_{ij}$ for degree 1 neighbors of group k
→ let other covariates unchanged.

- $\tilde{u}_{ij}$ is unobserved and cannot be estimated from the data.

→ We rely on 1000 Monte Carlo conditional draws of $\tilde{u}_{ij}(a)$ for predicting post-intervention rewired networks.

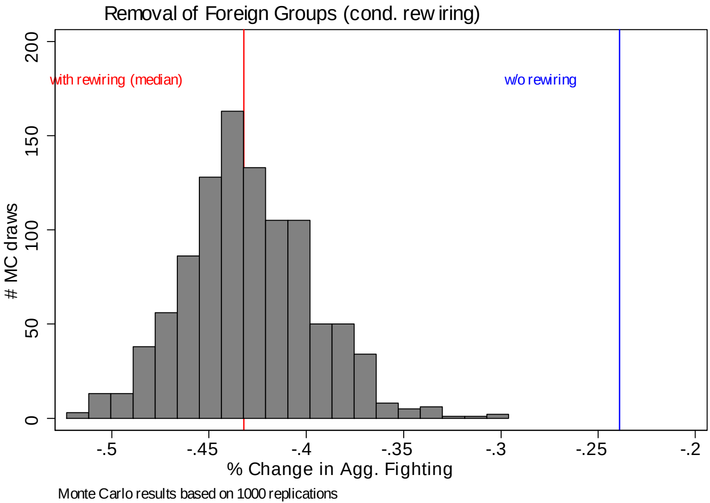
Network Recomposition

Key Player Analysis with rewiring - Comparison of Aggregate Fighting



Network Recomposition

Key Player Analysis with rewiring - Ex: Removing foreign groups



Conclusion

- New tool to analyze complex alliance/rivalry networks in conflicts
- Helps one to understand why violence may escalate or stay low
- Structural estimation of the model
- Quantitative Analysis of different types of interventions aimed at scaling down conflict (removing actors, pacifying enmities, etc.)
- The methodology can be exported to other war contexts

Network Recomposition

Key Player Analysis with rewiring - Multiple key player

- Results confirm key role of RCD-G, Rwanda and Uganda
- May Mayi Militia becomes more important
- FDLR less important.

Network Recomposition

One-step vs. multisteps

- So far, we only allow for one-step recomposition.
- However, recomposition can lead to further changes.
- Allow for n rounds of rewiring until we converge to a new steady state
    - convergence not guaranteed

Introduction

Why should economists care about conflict - I

- *Direct loss of human life*: Since 1945 an estimated 3.3 million people got killed in 25 interstate wars, and 16.2 million direct fatalities took place in 127 civil wars.
- *Indirect effect of wars on human life*: Works through diseases after the end of conflicts. Ghobarah, Huth and Russett (2003, APSR) find that the indirect fatalities are at least as large as direct casualties.

Introduction

Why should economists care about conflict - II

- *Large economic costs*. Civil wars tend to reduce growth by 2.3 percent per year, so the average civil war which lasts about 7 years reduces GDP by about 15 percent (Collier, 2007, The Bottom Billion).
- *Major obstacle to growth and development:* 20 of the world's 34 poorest countries are affected by armed conflict (OECD, 2009, Armed Violence Reduction).
- The study of conflict becomes an increasingly important area of development economics.

Summary Statistics

Table 1: Summary statistics.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Total Fighting	1190	5.23	22.72	0	300
Total Fighting of Enemies	1190	50.48	92.89	0	645
Total Fighting of Allies	1190	38.80	74.77	0	493
d^- (Number Enemies)	1190	2.61	3.59	0	20
d^+ (Number Allies)	1190	2.24	3.41	0	18
Foreign	1190	0.31	0.46	0	1
Government Organization	1190	0.20	0.40	0	1
Rain fall $(t-1)$	1190	125.35	26.36	58.02	197.35