Mining for Peace

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Motivation

- Raising global demand for minerals (green energy transition).
- Demand is increasingly met by industrial mining in Africa, Asia, and South America.
- Risk of resource-fuelled conflicts in some of these countries.
  - Evidence that resource extraction fosters civil conflict: Collier and Hoeffler (2004), Humphreys (2005), Brückner and Ciccone (2010), Dube and Vargas (2013), Bazzi and Blattman (2014), Berman et al. (2017), Hodler et al. (2023), ...
  - Evidence that this effect is stronger in ethnically diverse areas: Morelli and Rohner (2015), Berman et al. (2017), Adhvaryu et al. (2021), Hodler et al. (2023), ...
- Important to mitigate mining-related conflict risks in order to transform the mining sector into a facilitator of peace and prosperity in the Global South.

Our approach

- We focus on the role of geography.
- We agree with the recent literature that local resource rents and local ethnic diversity influence local conflict risks.
- But we view countries as interconnected systems and believe that there are important systemic effects.
- Hence, in our model, the spatial distribution of conflict risks depends on a country's entire mining and ethnic geographies.
- This model offers theoretical concepts that allow predicting the effects of new mines on aggregate and local conflict risks.
- We find that some new mines reduce a country's aggregate conflict risk – hence, mining for peace.

Contribution: Theory

- Novel model with arbitrary distributions of ethnic groups and resource rents in space.
- Focus on bargaining failure (Fearon 1995) resulting from the possibility of intra-ethnic coalitions at local and national levels (Morelli and Rohner 2015) .
- Mechanism design approach shows the impossibility of peace in case of ethnic segregation and spatial resource inequality.
  - *Peace deficit:* proxy for aggregate conflict risk
- Second-best analysis predicts local conflict risks.
  - *Local conflict exposure:* proxy for spatial distribution of conflict risks
- Key role of ethnic groups from resource-rich regions, which feel deprived of local resource rents (Berman et al. 2023).
  - More realistic picture of ethnic conflicts by endogenizing grievances and mobilization.

Contribution: Empirical validation of theoretical concepts

- Empirical validation of our theory-based proxies for aggregate and local conflict risks.
- Data from Sierra Leone:
  - Granular spatial data on ethnic groups, mining, and conflict.
  - Nice variation in mining geography.
  - External validity in a sample of 8 West African countries.
- State-of-the-art empirical strategy exploiting changes in global mineral prices.
- Bridge between different strands of the literature on ethnic diversity, natural resources, and conflict:
  - Cross-country studies (e.g., Collier and Hoeffler 2004, Esteban et al. 2012/2015)
  - Granular spatial studies (e.g., Adhvaryu et al. 2021, Berman et al. 2017, Eberle et al. 2020, McGuirk and Nunn 2020)

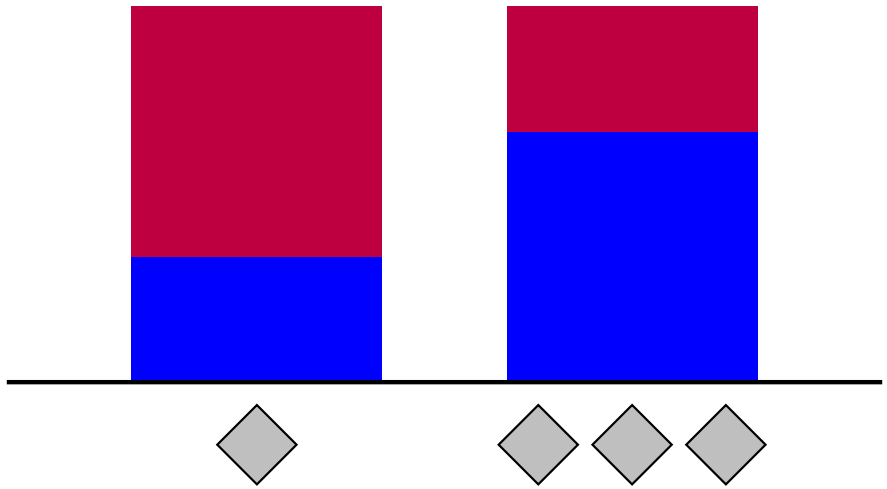
Contribution: Counterfactual policy analysis

- Simulations of (planned) new mining projects in Sierra Leone.
  - Δ peace deficit to predict Δ aggregate conflict risk.
  - Δ local conflict exposures to predict Δ spatial distribution of conflict risks.
- Large heterogeneity in aggregate and local effects.
- Mining for peace is possible in the right locations.
- Rich policy implications:
  - Least conflictual deposits to develop.
  - Peace deficit and the prize of mining licenses.
  - Local conflict exposure and "social licenses to operate."

Flavor of theory: Model

- General distributions of ethnic groups and resource rents across locations.
- Ethnic groups can contest resource rents at two levels:
  - Local conflicts: Local group members fight for local rents
  - National conflict: All group members fight for aggregate rents
  - Conflict is costly, and conflict costs are private information
  - Winning probabilities are proportional to group sizes
- Planner can transfer rents across groups and locations.
  - Metaphorically, planner represents the outcome of efficient bargaining between ethnic groups in the shadow of conflict.
- Planner's objective is:
  1. To guarantee peace at the national level
  2. To maximize the number of locations with peace (where we can add weights, e.g., to capture ethno-regional favoritism)

Flavor of theory: Problem (or why peace fails)



- Any ethnic group may start a national conflict unless they get a rent share proportional to their size.
- Planner transfers rents to groups over-represented in resource-poor locations to ensure national peace.
- Groups over-represented in resource-rich locations experience "discord" between high local resource rents and comparatively low post-transfer incomes and may start local conflicts.

Flavor of theory: Results

1. Impossibility to guarantee peace everywhere in presence of ethnic segregation and spatial resource inequality.
   - *Peace deficit:* hypothetical monetary amount necessary to guarantee peace everywhere, i.e., to pacify discordant groups in all locations.
   - It's our measure for the aggregate propensity to conflict.
2. Impossibility to implement peace via truthful revelation of private conflict costs in presence of ethnic segregation and spatial resource inequality.

Flavor of theory: Results

3. Characterization of second-best transfer scheme and the resulting spatial distribution of conflict risks:
   - *Local conflict exposure:*

$$e_l(\mathbf{t}_l, \mathbf{s}_l, r_l) := (r_l/r)\left[\prod_{g \in G^*} (s_l^g / s^g)\right]^{1/|G^*|}$$

   - It's our measure for the local propensity to conflict.
   - Intuition: Costs for "buying" local peace increase in
     - (relative) local resource rents,
     - local ethnic diversity among discordant groups G^*, which is high if discordant groups are manifold and locally over-represented.

Empirical setting

Empirical setting and sample

Sierra Leone:

- Civil war 1991–2002: $>$ 50,000 causalities
- Ethnicity is salient, but only one of several factors in the war.
- Diamond mining was important during the war, industrial bauxite and iron mining thereafter: 65% of export revenues, large share of government revenues.

Sample:

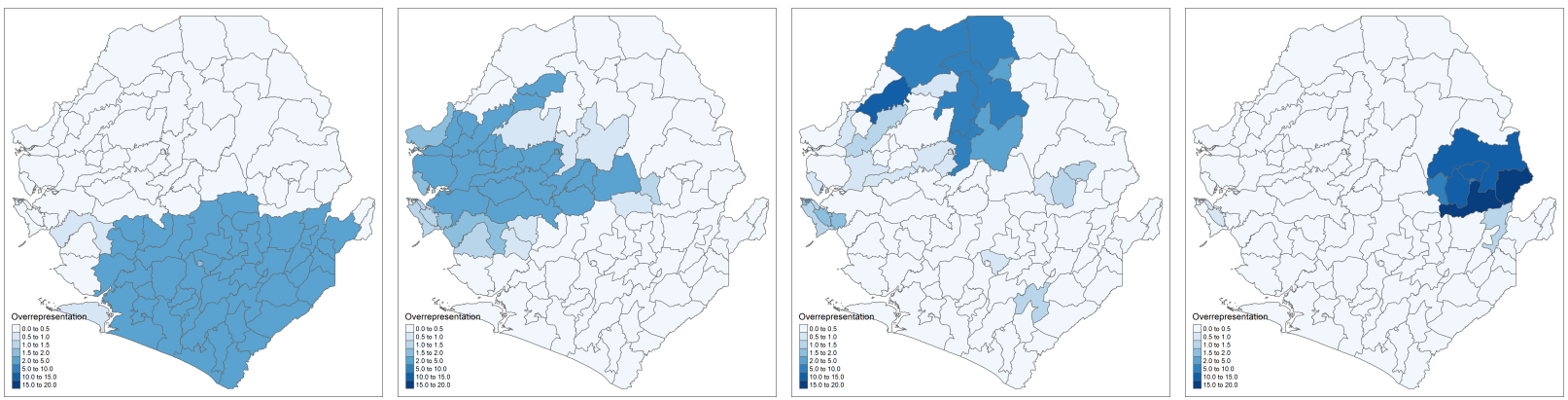
- Units: 107 wards in Sierra Leone.
  - Typically one or more historical chiefdoms.
  - Average area 670 km^2 ($<$1/4 of 0.5 $\times$ 0.5 DD grid cells).
- Sample period: 1997–2018.

Data: Ethnic geography

Data on population and ethnicity:

- Source: 2004 Housing and Population Census of Sierra Leone; 10% of all households; ward-level.
- Ethnic groups: Mende (33%), Temne (32%), Limba (8%), Kono (5%), plus 8 smaller, less important groups.

Figure: Local over-representation (s_l^g / s^g) of largest ethnic groups



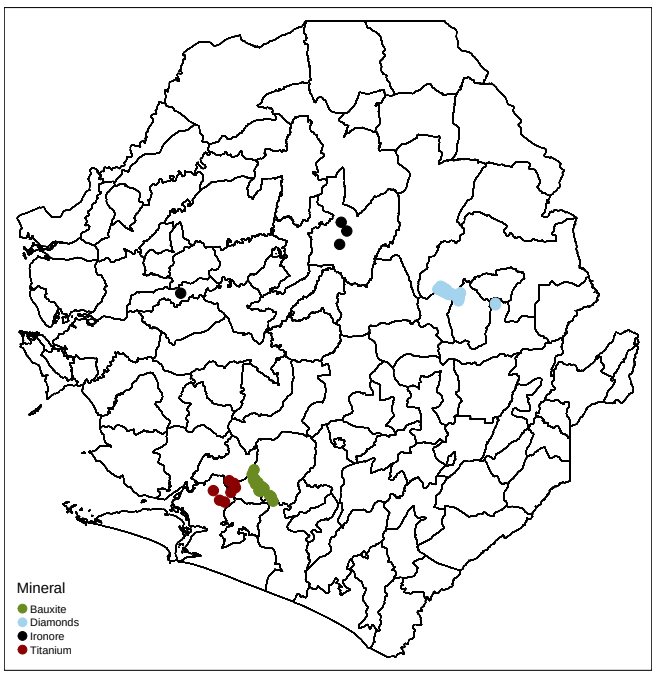
((a)) Mende ((b)) Temne ((c)) Limba ((d)) Kono

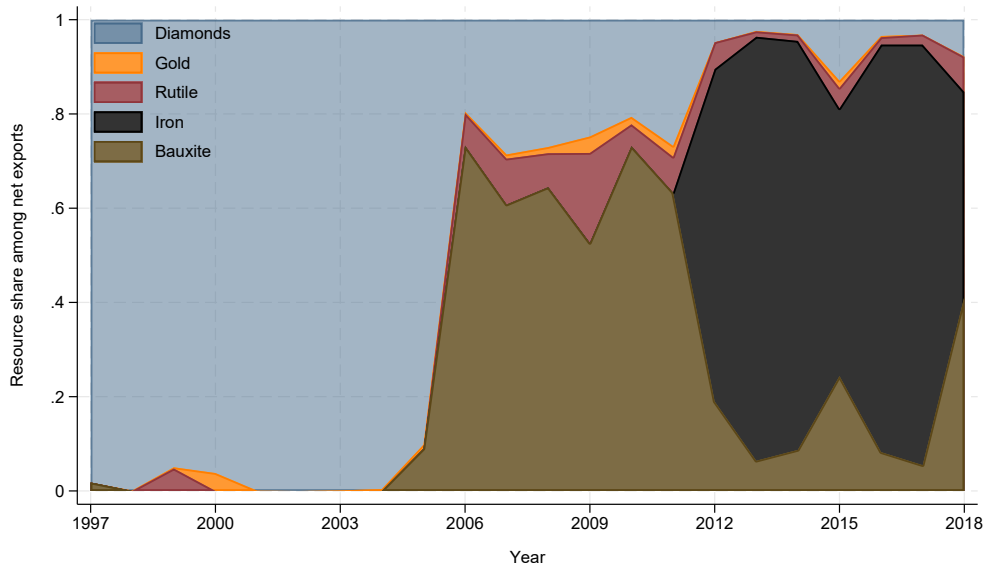
Data: Mining geography

Data on mining and minerals:

- Source for mines: Raw Material Data (RMD) plus polygons by Maus et al. (2020).
- Source for net exports: UN Comtrade
- Interesting variation:

Figure: Mining locations and net export shares

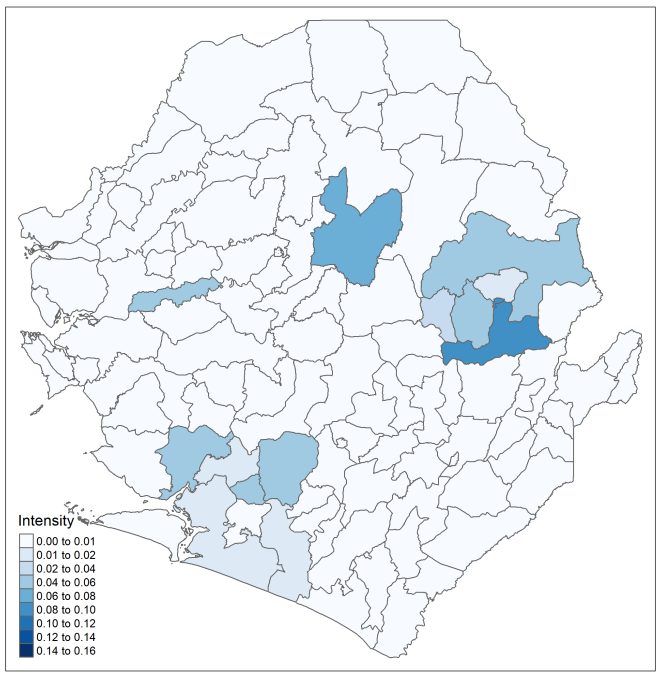




Data: Mining geography

- Assumption: Because of spatial spillovers from resource extraction, local resource rents r_l increase in
  - the size of nearby mines,
  - the inverse distance to these mines, and
  - the importance of the corresponding mineral in a given year.

Figure: Time-averaged relative local resource rents r_l/r

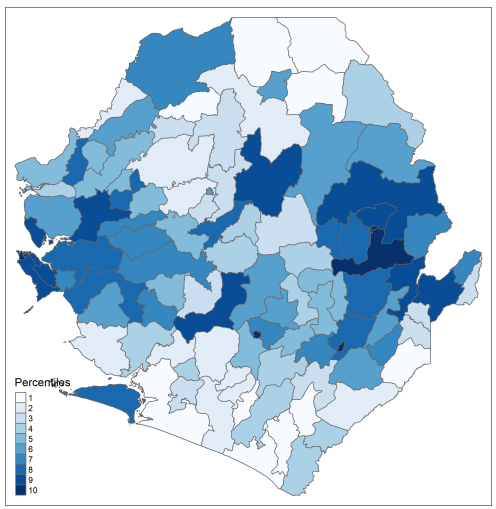


Data: Conflict

Observed local conflict exposure:

- Source: Armed Conflict Location and Event Data (ACLED)
- Events included: Battles, riots, violence against civilians (Eberle et al. 2020).
- Assumption: Observed local conflict exposure increases in
  - the number of nearby conflict events and
  - the inverse distance to these conflict events.

Figure: Time-averaged observed local conflict exposure

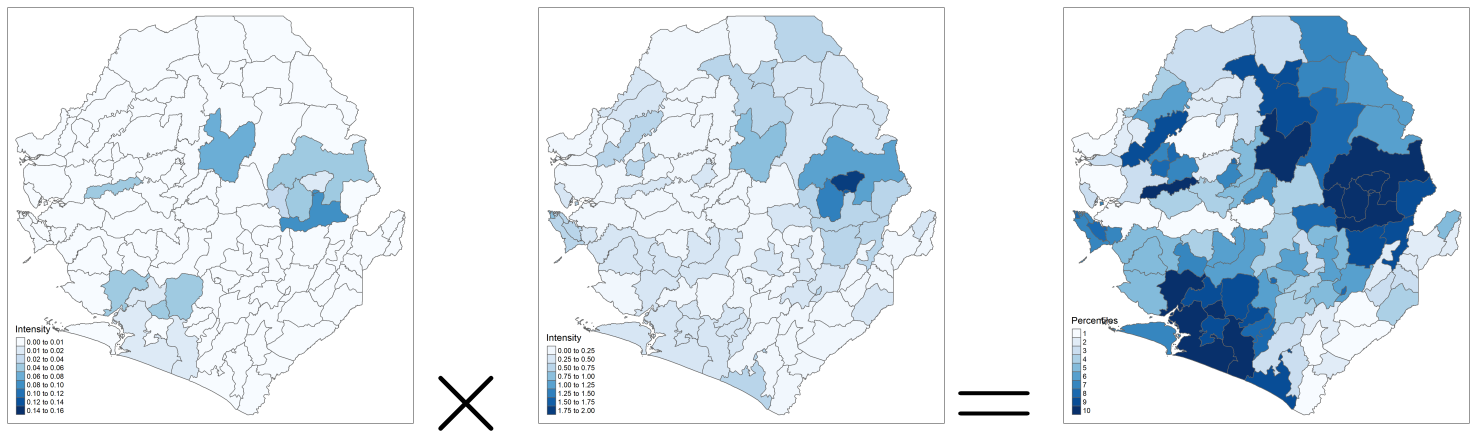


▸ Summary statistics

Empirical validation: Predicted local conflict exposure

Computation of predicted local conflict exposure:

1. Determine (country-level) set of discordant groups.
   - Examples: The Mende (Limba) are over-represented in the bauxite-mining (iron-mining) area and thus a discordant group in the bauxite (iron) period.
2. Compute ethnic diversity among discordant groups in each ward.
3. Compute predicted conflict exposure in each ward:



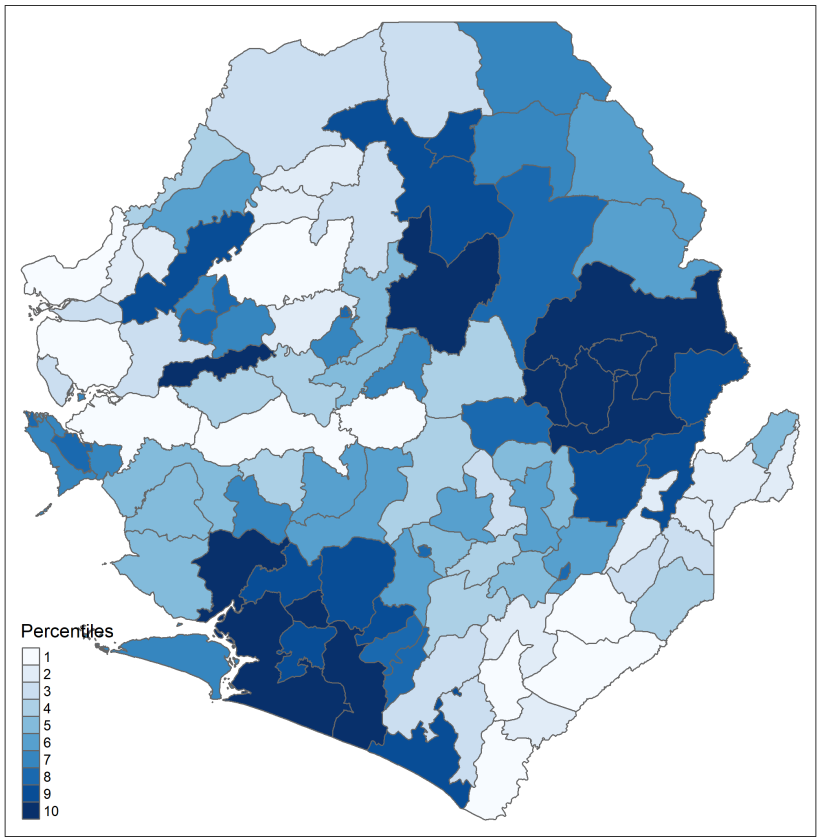
((a)) Relative resource rents

((b)) Diversity discordant groups

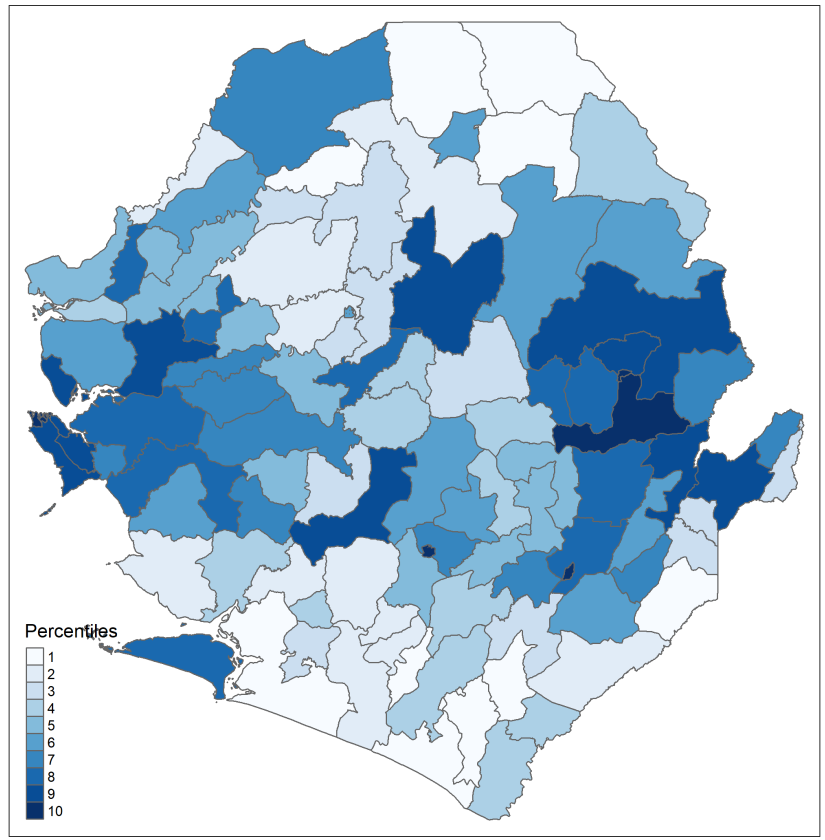
((c)) Predicted conflict exposure

Empirical validation: Visual econometrics

Figure: Time-averaged predicted vs observed local conflict exposures



((a)) Predicted conflict exposure



((b)) Observed conflict exposure

▸ Comparisons by period

Empirical validation: Cross-sectional OLS evidence

	Dependent variable: Log observed conflict exposure			
	(1)	(2)	(3)	(4)
Panel A: Full period				
Log predicted conflict exposure	0.140***	0.120***	0.055**	0.053*
	(0.044)	(0.041)	(0.024)	(0.028)
R2	0.0648	0.245	0.773	0.833
Panel B: Diamond period				
Log predicted conflict exposure	0.097***	0.085***	0.068**	0.089**
	(0.023)	(0.016)	(0.030)	(0.035)
R2	0.0967	0.238	0.537	0.684
Panel C: Bauxite period				
Log predicted conflict exposure	0.105**	0.117***	0.065**	-0.021
	(0.048)	(0.044)	(0.027)	(0.032)
R2	0.0649	0.245	0.736	0.794
Panel D: Iron period				
Log predicted conflict exposure	0.174*	0.127*	0.091***	0.071**
	(0.096)	(0.074)	(0.031)	(0.028)
R2	0.0695	0.218	0.762	0.832
Population control	–	✓	✓	✓
Area control	–	–	✓	✓
Province-fixed effects	–	–	–	✓
Observations	107	107	107	107

Notes: Standard errors are spatially clustered with a distance cutoff of 100km.

Empirical validation: Panel and IV evidence

- Exploit intertemporal variation in two-way fixed effects regressions.
- Endogeneity concern: Conflict reduces mining activities and, thereby, local resource rents and predicted conflict exposure.
- Common practice: Use variation in global mineral prices.
- Strategy: Use shift-share instruments for identification via exogenous (global price) shocks (Borusyak et al. 2022).
- First stage: $\ln(\text{Predicted conflict exposure}_{lt}) =$

$$\sum_{j=B,D,I} \delta_j [\ln(\text{proximity}_l^j) \times \ln(\text{price}_t^j)] + FE_l + FE_t + \nu_{lt},$$

where B, D and I stand for bauxite, diamonds, and iron.

Empirical validation: Panel and IV evidence

	Dependent var.: Log observed conflict exposure			
	(1)	(2)	(3)	(4)
Panel A: OLS				
Log predicted conflict exposure	0.064***	0.047***	0.041**	0.041**
	(0.020)	(0.017)	(0.018)	(0.020)
R2	0.516	0.560	0.567	0.583
Panel B: 2SLS (second stage)				
Log predicted conflict exposure	0.189***	0.171**	0.165**	0.161***
	(0.066)	(0.069)	(0.069)	(0.059)
R2	0.496	0.543	0.552	0.570
Panel C: 2SLS (first stage) – Dependent variable: Log predicted conflict exposure				
Bauxite proximity-price interaction	2.643***	2.882***	3.102***	3.286***
	(0.460)	(0.434)	(0.448)	(0.407)
Diamond proximity-price interaction	-2.924***	-1.583***	-0.668*	-0.650
	(0.331)	(0.359)	(0.362)	(0.426)
Iron proximity-price interaction	0.311***	0.157	-0.014	-0.439***
	(0.112)	(0.113)	(0.119)	(0.157)
First-stage F-stat	43.42	22.34	19.18	25.12
Ward-fixed effects	✓	✓	✓	✓
Year-fixed effects	✓	✓	✓	✓
Province trends	–	✓	–	–
District trends	–	–	✓	–
Ward trends	–	–	–	✓
Observations	2354	2354	2354	2354

Notes: Standard errors are spatially clustered with a distance cutoff of 100km.

Empirical validation: Robustness and external validity

Robustness: ▸ Figures and tables

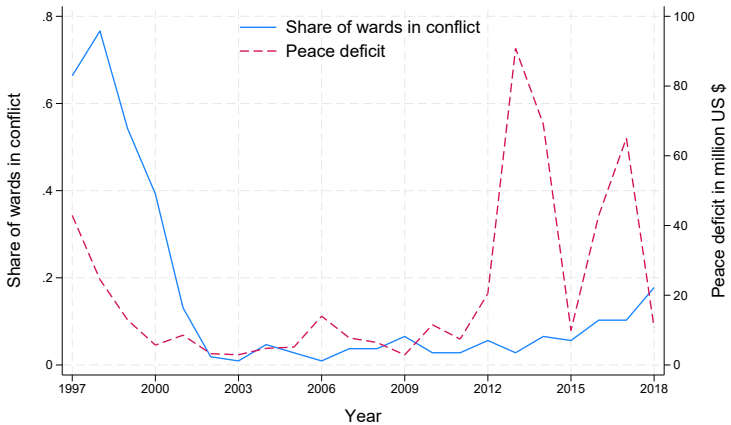
- All or different types of conflict events (or actor types)
- Inclusion of artisanal and small-scale mining
- Restriction to four largest ethnic groups
- Alternative distance decays
- Alternative distance cutoffs for spatially clustered SE
- Controlling for local resource rents and Berman et al. (2017) interaction term

External validity: ▸ Figures and tables

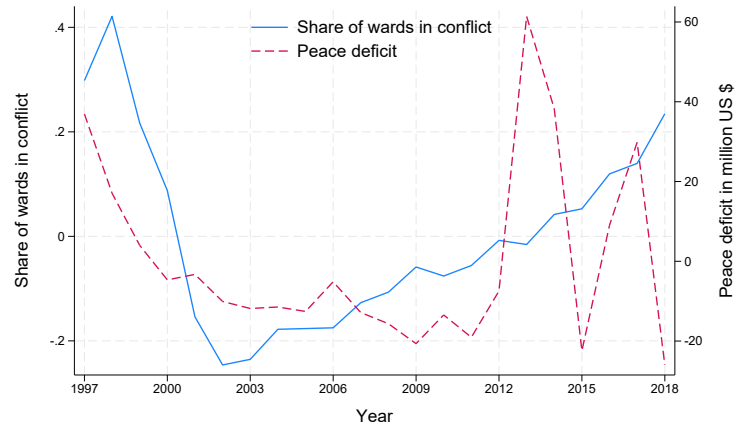
- Similar cross-sectional results in a sample of 8 West African countries with less granular spatial data.

Empirical validation: Peace deficit

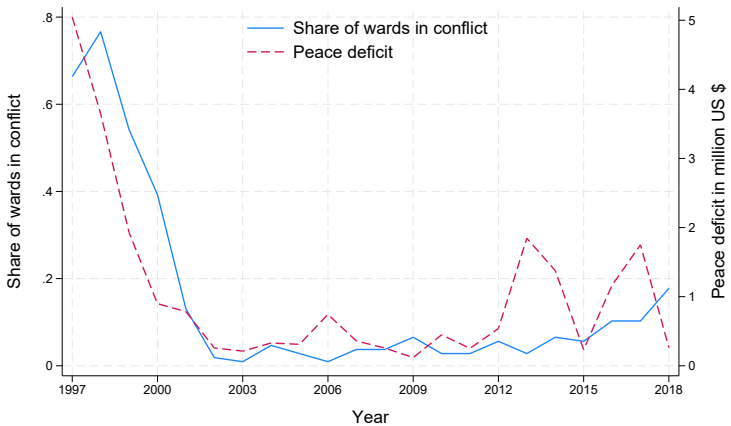
Figure: Changes in country-wide propensity for conflict over time



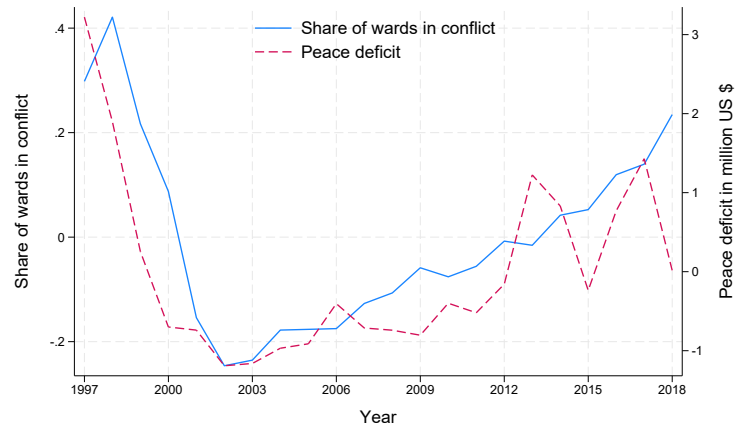
((a)) No adjustment



((b)) Detrended time series



((c)) PD normalized by GDP

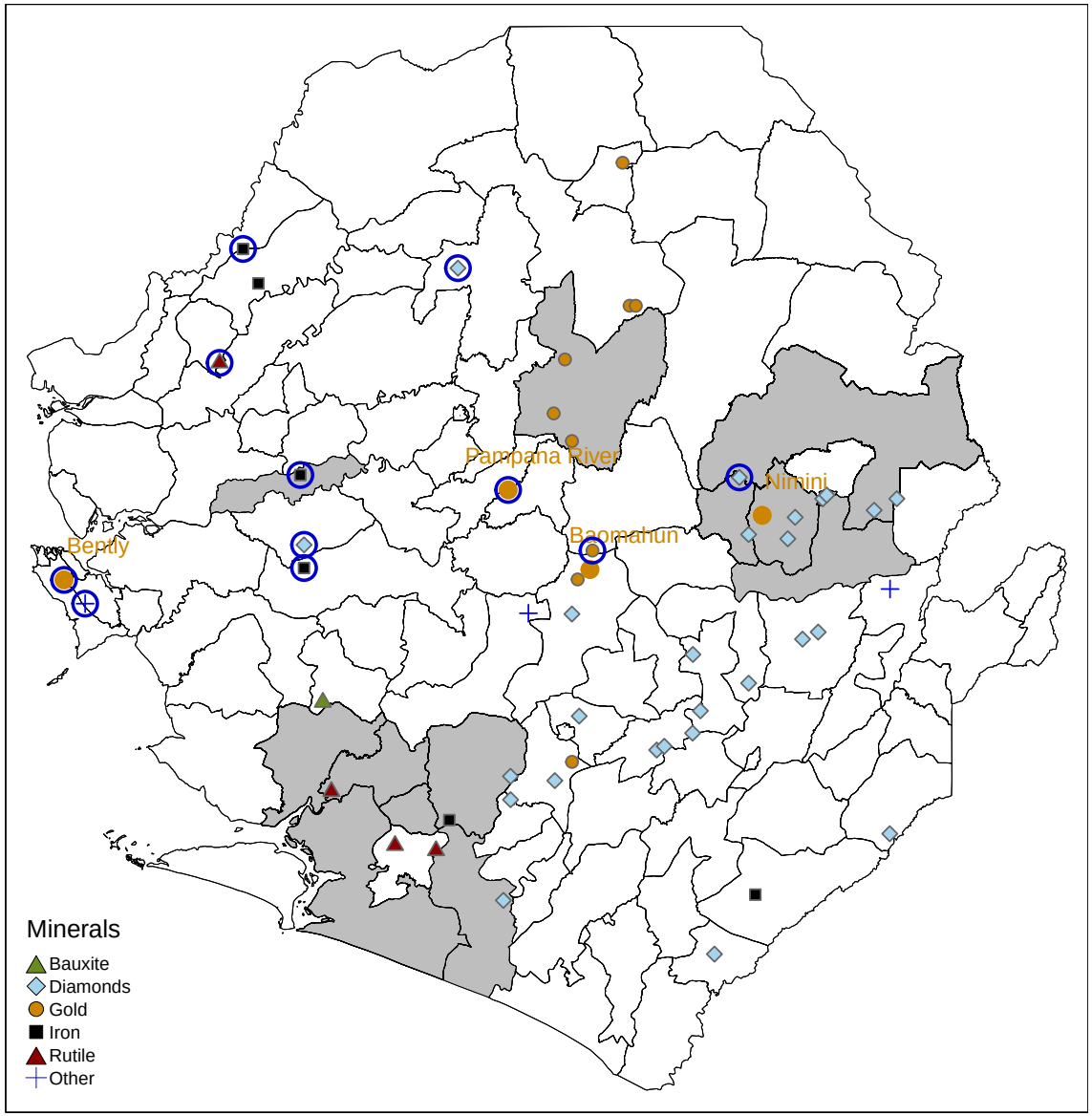


((d)) Both adjustments

Notes: Correlation coefficient is (a) 0.076, (b) 0.399, (c) 0.824, and (d) 0.795.

Counterfactual analysis

Question: Effect of developing known mineral deposits on conflict?



Counterfactual analysis

Idea:

- Use changes in peace deficit to predict effects on aggregate propensity for conflict.
- Use changes in local conflict exposure to predict relative effects across locations.

Decomposition of these effects:

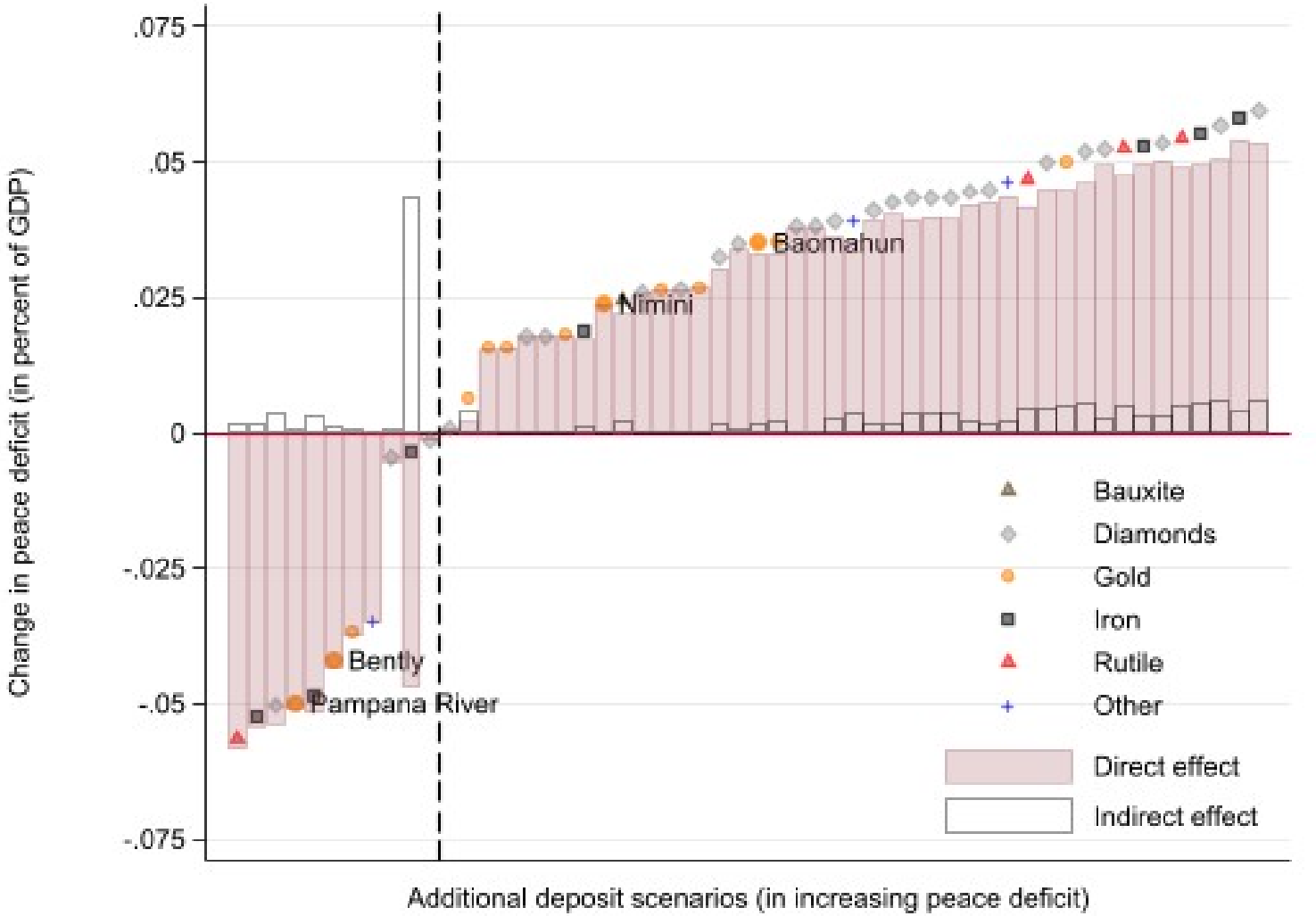
- Direct effect due to changes in the spatial distribution of resource rents.
- Indirect effect due to changes in the set of discordant groups.

Assumptions (easy to modify):

- Revenues of existing mines: unchanged.
- Revenues of new mines: 10% of current total mining revenues.

Counterfactual analysis

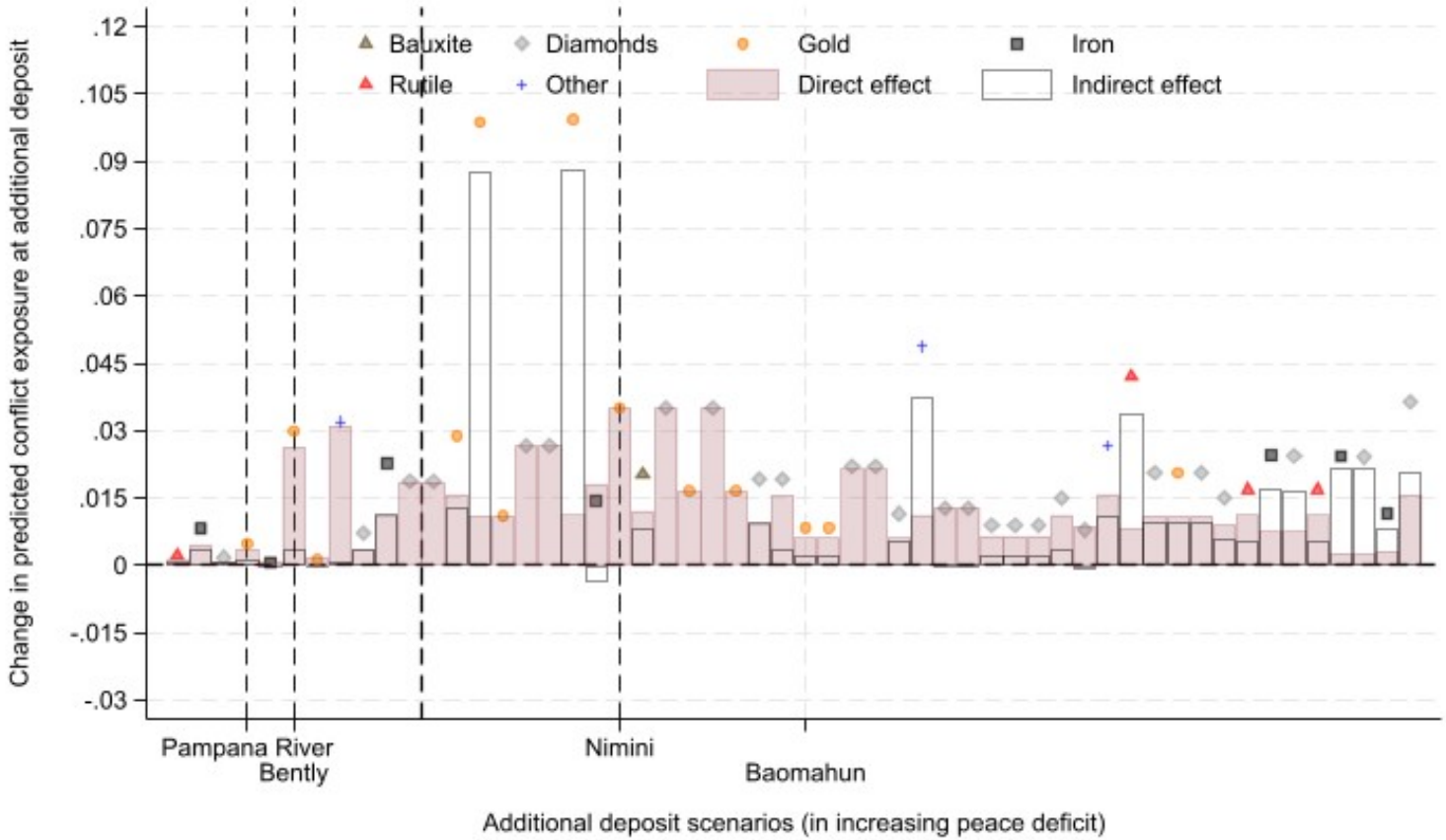
Figure: Aggregate effects of new mining projects on conflict



- Mining for peace is rather rare, but possible.

Counterfactual analysis

Figure: Effects of new mining projects on local conflict at deposits



- Effects are positive for all deposits.
- Large variation and no clear correlation with aggregate effects.

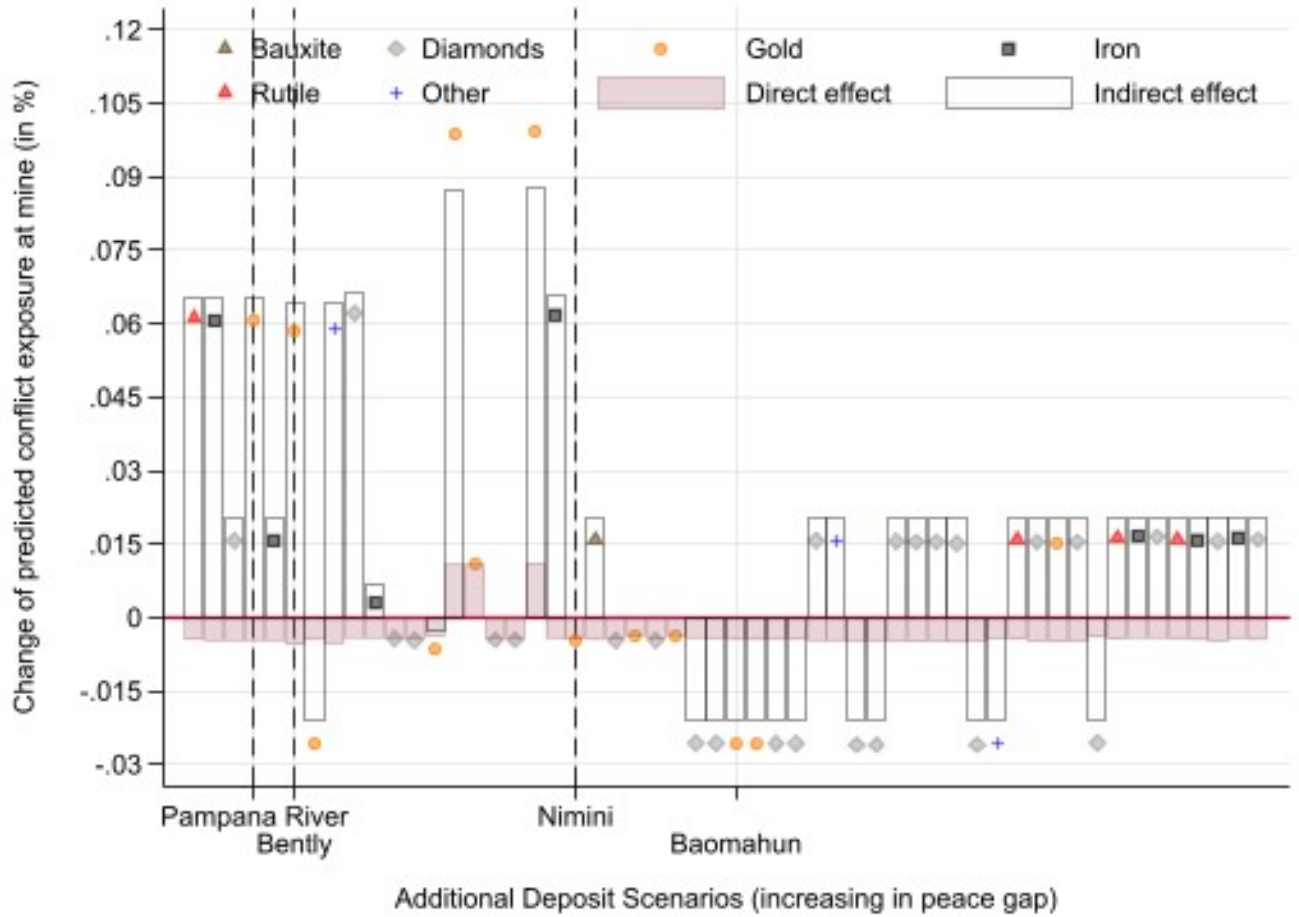
Counterfactual analysis

Intuition: Pampana River deposit

- Location: Close to the center (slightly towards the west).
- Reasons for negative aggregate conflict externalities:
  - Reduction in spatial resource inequality, as no active mine is nearby.
  - Increase in resource rents in locations where discordant groups are under-represented.
  - Reduction in ethnic diversity among discordant groups in some resource-rich locations as the Kono are no longer discordant.
    - Kono live in the diamond-mining area in the East.
- Reasons for low local conflict externality:
  - Low ethnic diversity among discordant groups, as they are all locally under-represented.
  - This would change if local revenues were higher, such that the Temne, who are locally over-represented, became a discordant group.

Counterfactual analysis

Figure: Effects of new mines on local conflict at Tonkolili Mine



- Again: a lot of variation, but now indirect effects dominate.

Conclusions and policy implications

- We argue that the effects of new mines on conflict depend on:
  - Location of new mines and local ethnic diversity.
  - Country's entire mining and ethnic geographies.
- Our theoretical model offers two concepts: peace deficit and local conflict exposure.
- Our empirical analyses validate these concepts.
- Our counterfactual analyses use these concepts and show that new mines have very different effects on aggregate and local conflict risks.
- Our concepts and simulations can be useful for governments, international mining companies, and other stakeholders.

Conclusions and policy implications

Governments:

- Use the change in the peace deficit to shape the set of active mines or to price mining licences or design royality schemes.
- Use the change in local conflict exposure if concerned about conflict in economically or politically important locations.

International mining companies:

- Use our concepts because conflict can increase production and transportation costs.
- Use our concepts because conflict can undermine the social license to operate (i.e., society's approval of their activities).
- Use our concepts for human rights due diligence, required by the UN Guiding Principles on Business and Human Rights and expected to soon include conflict and violence.

Appendix

Theory: Setup

- Country with ethnic groups $g = 1...G$ and locations $l = 1...L$.
- Each location has a resource rent $r_l > 0$, with $r = \sum_l r_l$.
- Resource rents can be contended in local or national conflicts.
- Group g (in location l) believes that the share of the rents preserved in a local/national conflict is $v_l^g \in [0,1]/v^g \in [0,1]$.
- Group g (in location l) wins the share $s_l^g \in [0,1]/s^g \in [0,1]$ of the preserved rents in a local/national conflict.
  - These shares may depend on a group's local and national population m_l^g and m^g, e.g., ratio forms $s_l^g = m_l^g/m_l$ and $s^g = m^g/m$.
- Group g's payoff from local/national conflict is $r_l v_l s_l^g / rvs^g$.

Theory: Setup

- A central planner can redistribute resource rents.
- A transfer system $\mathbf{t}$ is a $|G| \times |L|$ dimensional matrix with t_l^g as typical element.
- A transfer system is *budget feasible* iff $\sum_g t_g \leq r$.
- Group g's payoff from peace is t_l^g / t^g at the local/national level, where $t^g = \sum_l t_l^g$.
- The planner's objective is to (i) guarantee peace the national level and (ii) maximize the number of locations with peace.
  - Benevolent political leaders are rare, but even non-benevolent leaders care about security and stability.
  - Other objectives (e.g., ethnic or regional favoritism) would imply a tightening of the budget constraint, making ours a best-case scenario.

Theory: Peace guaranteeing transfers

Main result:

- **Proposition 1:** There exists a transfer system that is budget feasible and implements peace everywhere if and only if

$$1 = \sum_{l} (r_l/r)(s_l^g/s^g) \text{ for each } g. \tag{1}$$

- Assuming ratio forms, peace condition (1) holds only in very special cases:
  - No spatial resource inequality, i.e., $r_l/m_l = r/m$ for all l.
  - No ethnic segregation, i.e., $m_l^g/m_l = m^g/m$ for all l and g.

Theory: Peace guaranteeing transfers

Intuition:

- A transfer system implements peace everywhere for all v^g and v_l^g if and only if $t^g \geq s^g r$ and $t_l^g \geq s_l^g r_l$ for all g and l.
- First, each group gets $t^g = s^g r$ to guarantee national peace.
- Groups over-represented in resource-rich locations are then short of (local) transfers from this national-level constraint:

$$rs^g = t^g = \sum_{l \in L} t_l^g < \sum_{l \in L} r_l s_l^g$$

- Formally, the set of these groups is

$$G^* = \{g \in G : 1 < \sum_{l \in L} (r_l/r)(s_l^g/s^g)\}$$

- These groups feel deprived of the resource rents accruing in the locations where they predominately live.
- They may start local conflicts (unlike other groups).

Theory: Peace guaranteeing transfers

Remark:

- Bargaining failure follows from the presence of multiple threat points.

Useful measure:

- We define the peace deficit as the amount of extra funds that would allow the planner to guarantee peace everywhere:

$$D := \sum_{g \in G^*} \left(\sum_{l \in L} r_l s_l^g - r s^g \right)$$

- It measures the general tendency to conflict in a country.

"Extension:"

- **Proposition 2:** There exists a mechanism that is peace maximizing and incentive compatible if and only if peace condition (1) holds.

Theory: Second-best transfers

- Government minimizes aggregate probability of local conflict subject to ensuring peace at the national level:

$$\min_{t} \sum_{l} p_l(t_l, ...) \text{ s.t. } t^g = s^g r \text{ for each } g.$$

- Deprived groups $g \in G^*$ are again conflict initiators.
- Assumption: Groups' signals of preserved shares are iid with power-form CDF $\Phi(x) = x^\alpha$ with α sufficiently small.
- **Proposition 3:** Given the optimal system of transfers, the probability of conflict at each location $l \in L$ is increasing in the conflict exposure index

$$e_l(\mathbf{t}_l, \mathbf{s}_l, r_l) := (r_l/r) \left[\prod_{g \in G^*} (s_l^g / s^g) \right]^{1/|G^*|}.$$

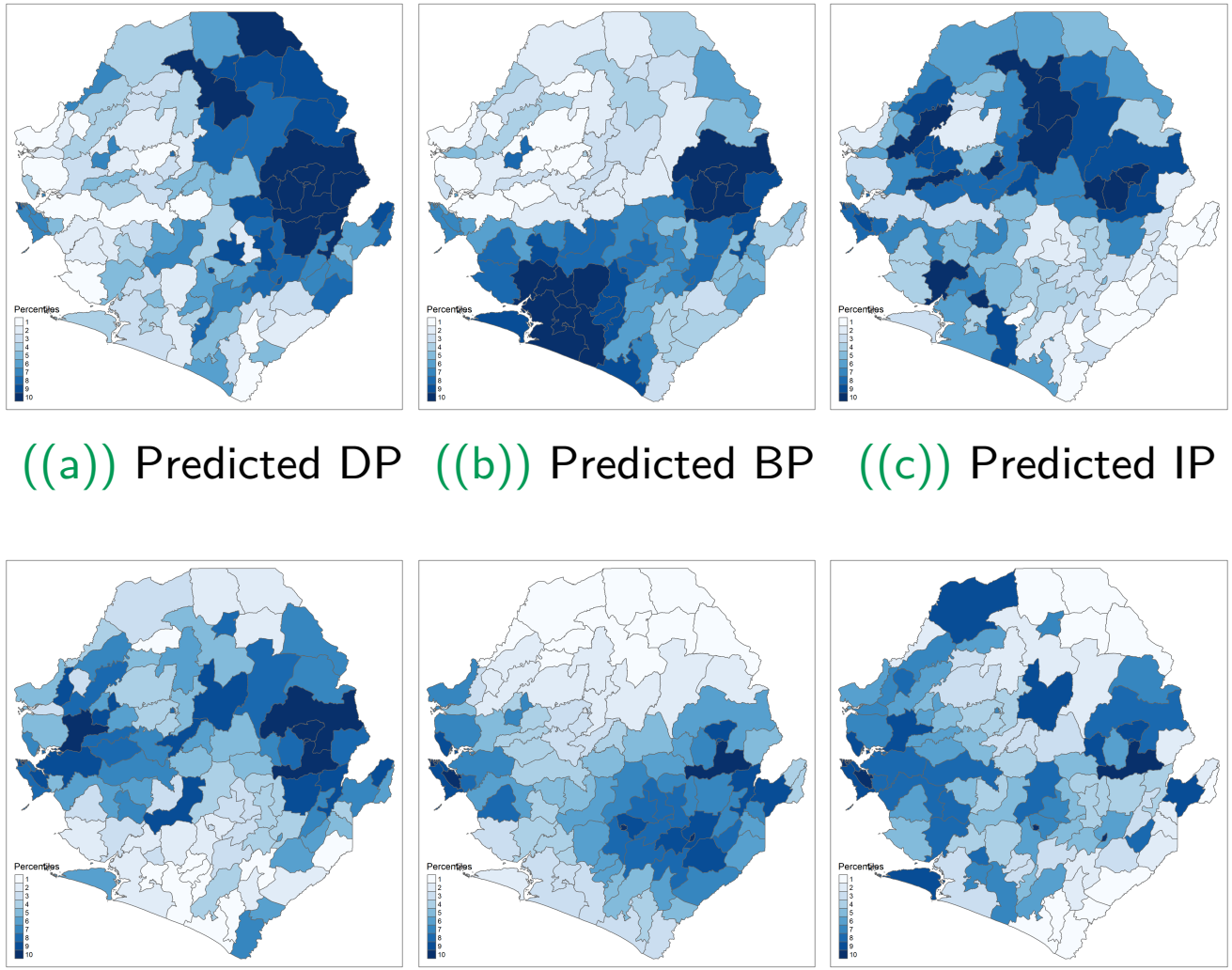
Data: Summary statistics

Variable	Mean	SD	Min	Max	N
Panel A: Cross-sectional sample					
Relative resource rents	0.01	0.02	0.00	0.10	107
Diversity among discordant groups	0.34	0.30	0.04	1.76	107
Log observed conflict exposure	-5.51	0.65	-6.33	-3.00	107
Log predicted conflict exposure	-7.04	1.18	-9.13	-2.63	107
Log population (2004)	10.57	0.50	9.53	12.67	107
Log area	5.93	1.61	-0.23	7.97	107
Panel B: Panel sample					
Log observed conflict exposure	-5.51	1.04	-7.43	-0.81	2,354
Log predicted conflict exposure	-7.04	1.68	-11.24	-0.16	2,354
Log bauxite proximity $\times$ log bauxite price	-41.58	6.24	-50.90	-10.82	2,354
Log diamond proximity $\times$ log diamond price	-24.96	4.25	-30.48	-7.91	2,354
Log iron proximity $\times$ log iron price	-20.74	5.07	-32.06	-3.34	2,354
Panel C: Time-series sample					
Share of wards in conflict	0.15	0.22	0.01	0.77	22
Peace deficit in percent of GDP	1.03	1.23	0.12	5.05	22

◂ Return

Empirical validation: Visual econometrics

Figure: Predicted vs observed local conflict exposures across periods



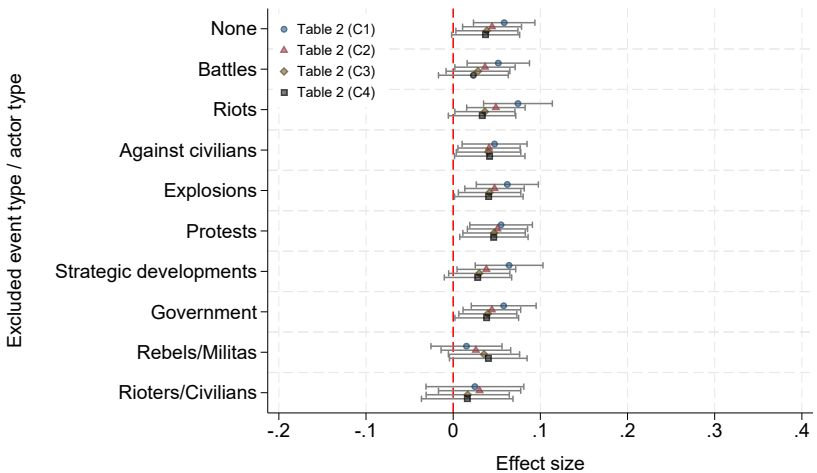
((a)) Predicted DP ((b)) Predicted BP ((c)) Predicted IP

((d)) Observed DP ((e)) Observed BP ((f)) Observed IP

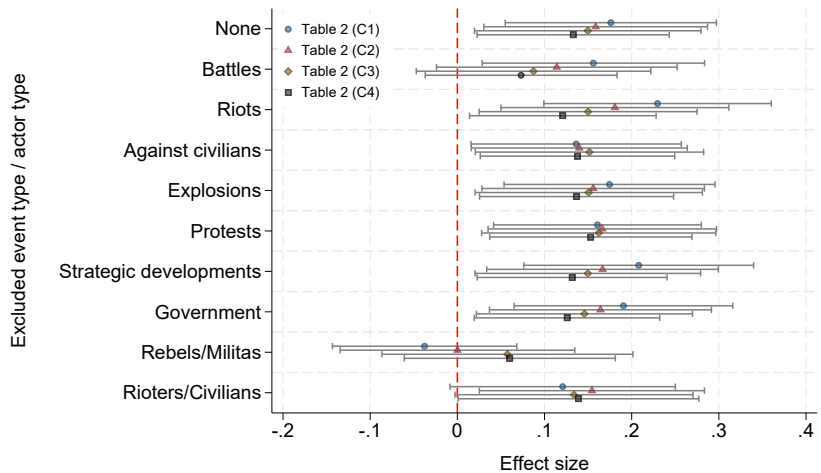
◂ Return

Robustness

Figure: Alternative outcome variables



((a)) OLS panel

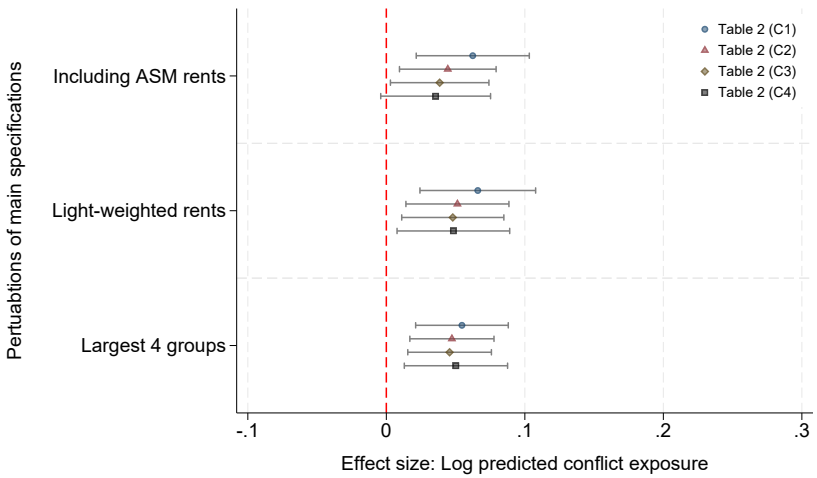


((b)) 2SLS panel (second stage)

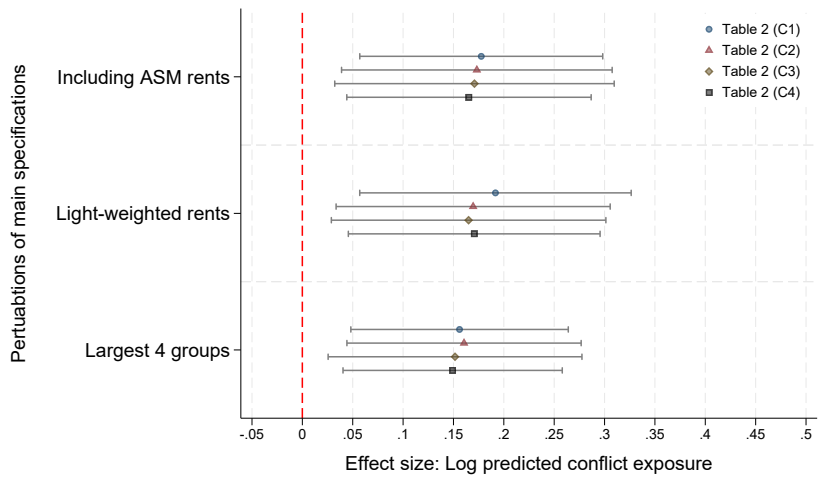
◂ Return

Robustness

Figure: Alternative independent variables



((a)) OLS panel

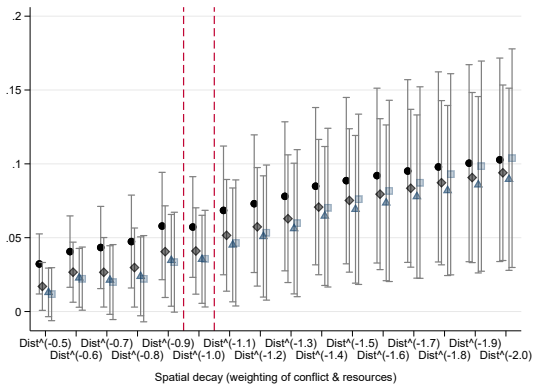


((b)) 2SLS panel (second stage)

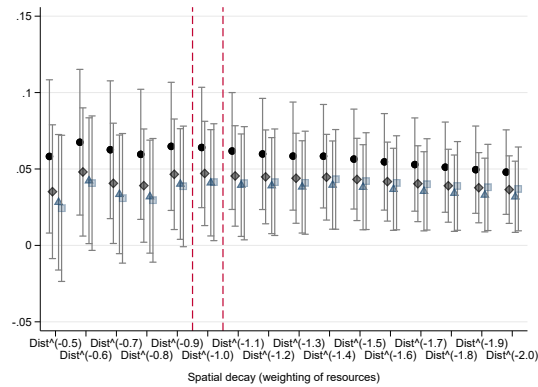
◂ Return

Robustness

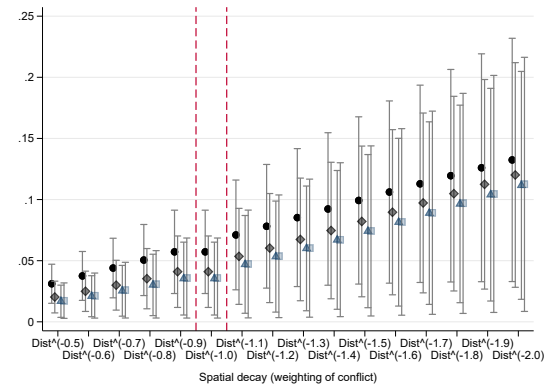
Figure: Alternative distance decays



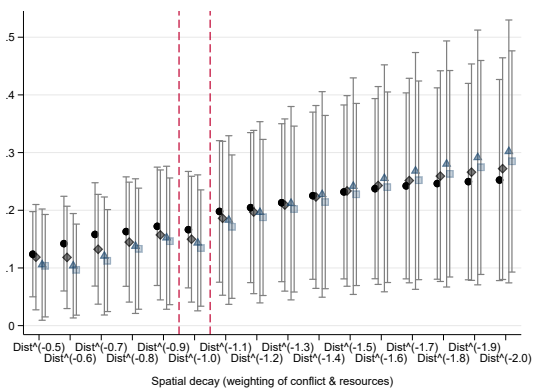
((a)) OLS panel (both)



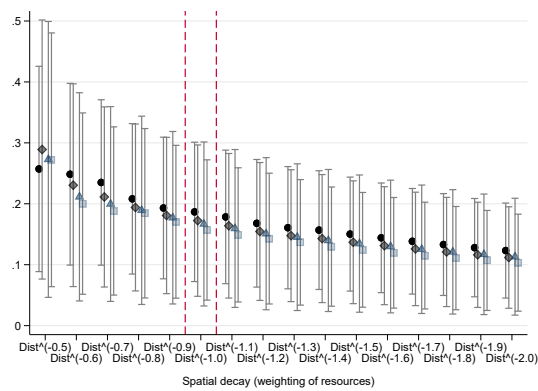
((b)) OLS panel (rents)



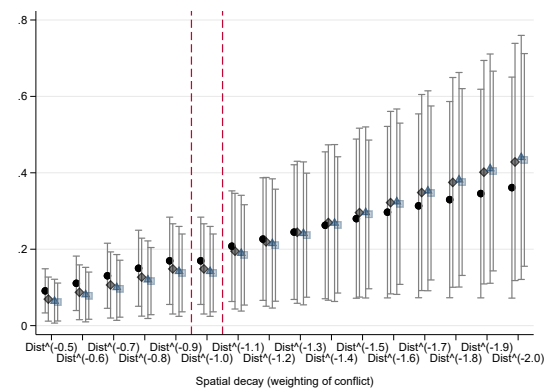
((c)) OLS panel (conflict)



((d)) 2SLS panel (both)



((e)) 2SLS panel (rents)

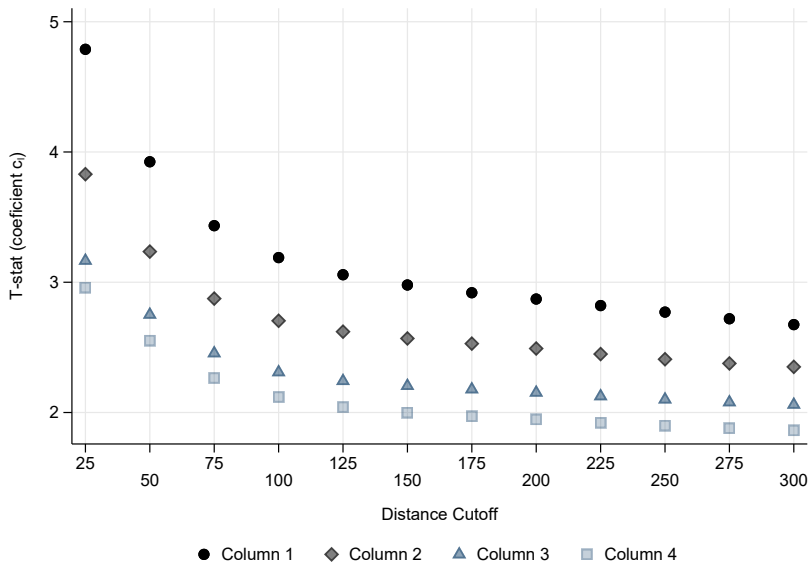


((f)) 2SLS panel (confl.)

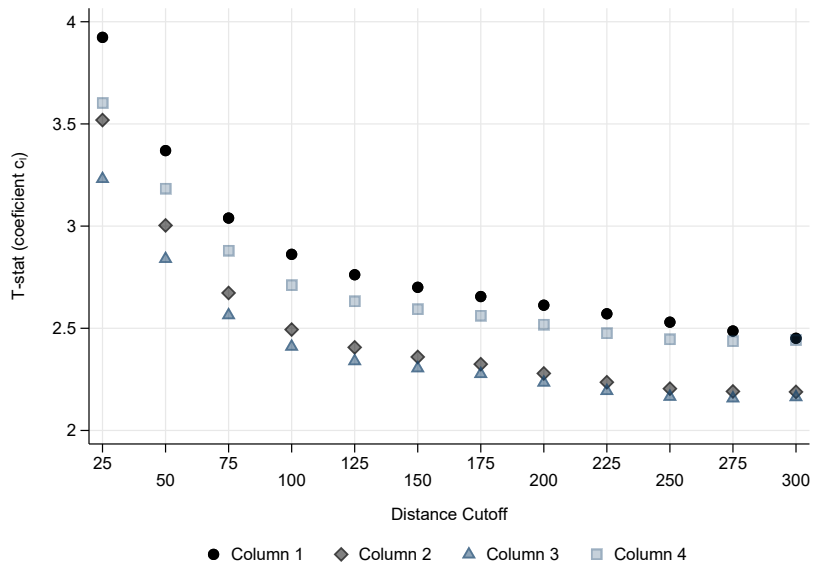
◂ Return

Robustness

Figure: Alternative distance cutoffs for spatially clustered standard errors



((a)) OLS panel

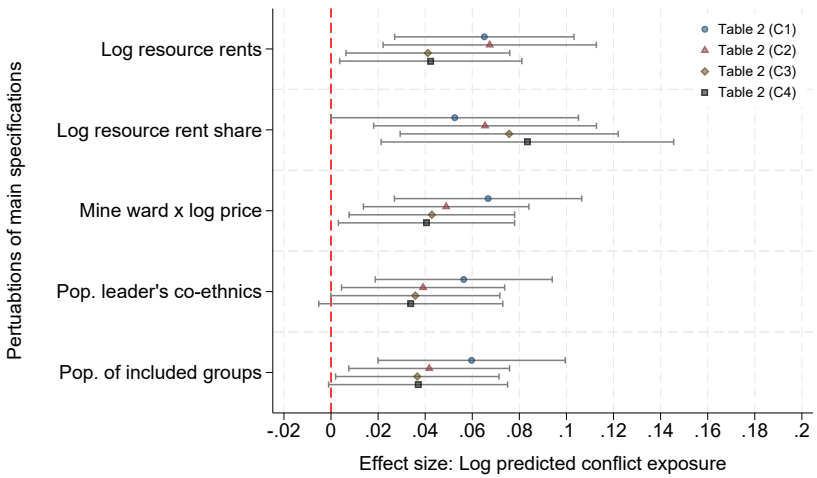


((b)) 2SLS panel

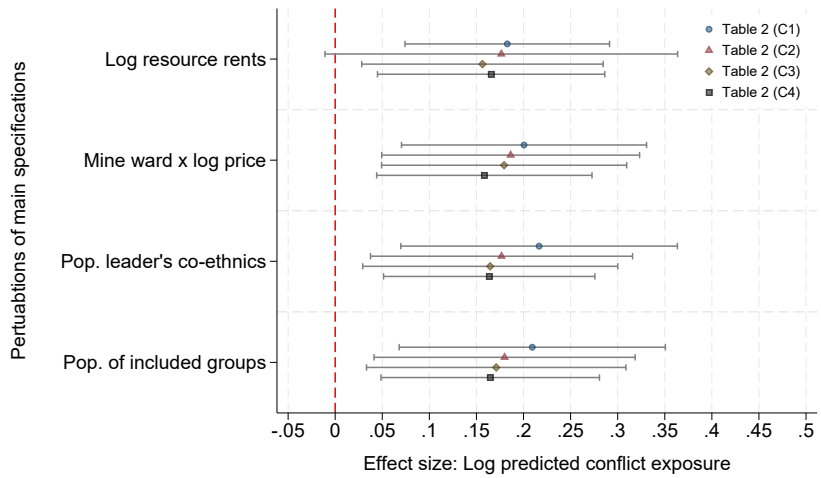
◂ Return

Robustness

Figure: Ward-level control variables



((a)) OLS panel



((b)) 2SLS panel (second stage)

◂ Return

External validity

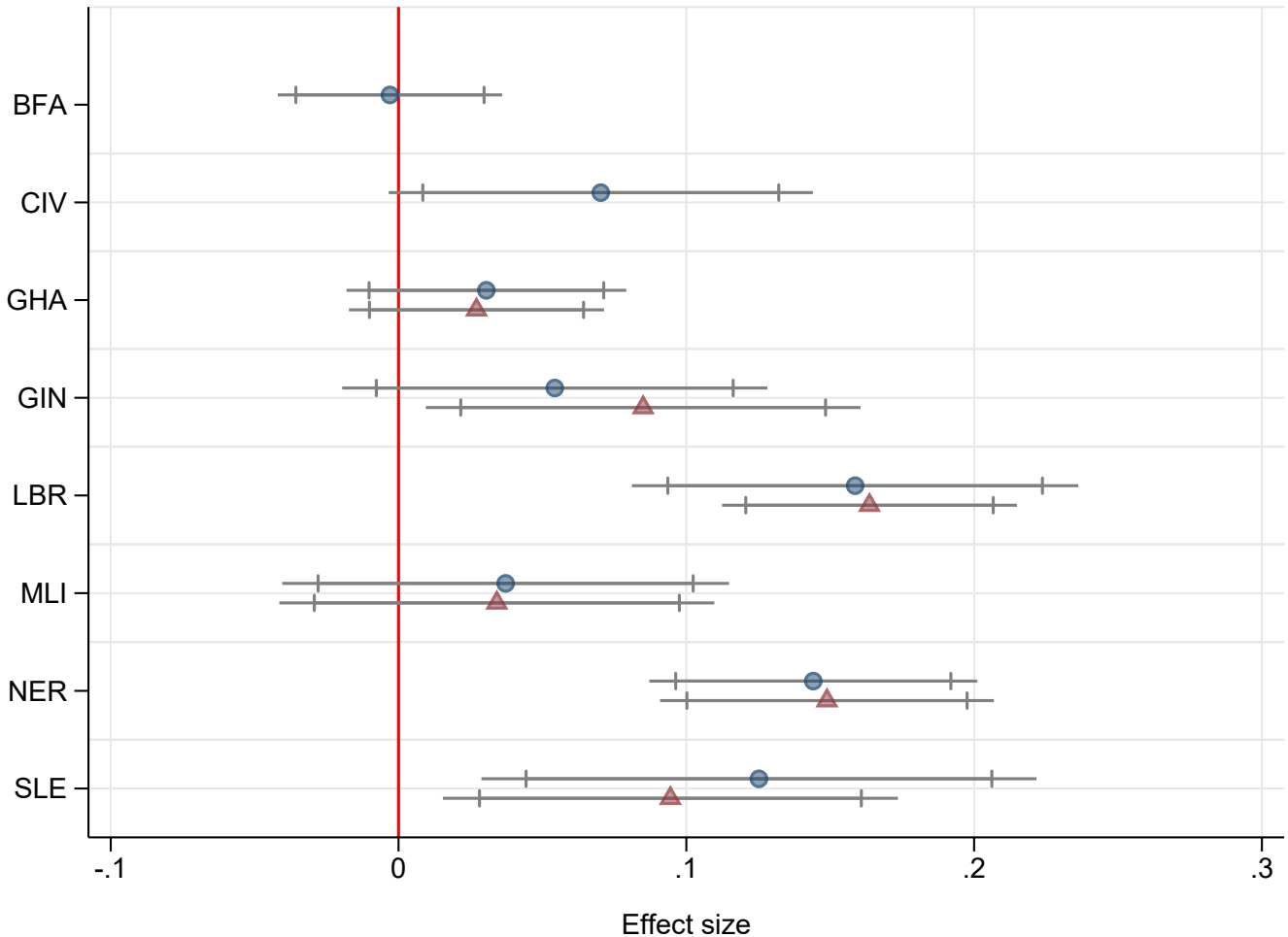
Table: External validity

	Dependent variable: Log observed conflict exposure			
	Sierra Leone		*West Africa*	
	(1)	(2)	(3)	(4)
Panel A: All ethnic groups				
Log predicted conflict exposure	0.121**	0.150***	0.074***	0.061***
	(0.059)	(0.053)	(0.015)	(0.013)
Obs.	39	39	1534	1534
Panel B: Politically relevant ethnic groups				
Log predicted conflict exposure	0.103**	0.117***	0.090***	0.090***
	(0.040)	(0.040)	(0.015)	(0.015)
Obs.	39	39	1275	1275
Population and area controls	–	✓	–	✓
Country-fixed effects	✓	✓	✓	✓

◂ Return

External validity

Figure: External validity: Single-country estimates



◂ Return