MiningLeaks: Water Pollution and Child Mortality in Africa

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Motivation and research question

→ Ambiguous effects of industrial mining activity on local population's health

- **Positive externalities :** local industrial development, job creations, consumption, access to services and facilities (health centers, roads...) [Kotsadam and Tolonen, 2016 ; Mamo, Moradi et al. (2019)]
- **Negative externalities :** exposure to pollution, conflicts, corruption, migration [Atkin, 2016 ; Corno and de Walque 2012 ; Berman, Couttenier et al. (2017) ; Aragon and Rud (2016)]

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Research question

- What are the effects of **mining-induced water pollution** on child mortality in Africa ?

Effects on health when exposure is proxied by distance

- Tolonen (2018) : decrease of infant mortality within 10km (*vs.* [10km ;100km]) during the opening/operating phases across 8 countries in SSA

- Von der Goltz and Barnwal (2019) : gains in asset wealth, but increased women's anemia/stunting in young children within 5km (*vs.* [5km ;20km])

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Our contributions

→ Build a dataset of industrial mining activity - handchecked start up years

→ Take into account the topography of villages and industrial mining sites to capture the effects of mining-induced water pollution on health

This paper

Question

→ What are the effects of industrial mining- induced water pollution on children's mortality in Africa ?

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→ Demographic Health Survey (DHS), 26 countries 1986-2018

→ SNL Mining and Metals + manual work : 2,016 mines crossing DHS

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Method

→ Two-way fixed effects using topographic position to proxy exposure to a mine. Matching strategy reduces bias when using distance as proxy

→ Compare 12 and 24 months mortality rates of villages upstream *vs.* downstream, before *vs.* after the opening of a mine

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→ Compare 12 and 24 months mortality rates of villages upstream *vs.* downstream, before *vs.* after the opening of a mine

Results

→ Being downstream of a mine opening increases by 27% the 24 months mortality rate

→ Effects persistent up to 3 years after the mine opens, and start during the investment phase

Outline

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Data : SNL Mining and Metal

- Privately-owned and on license
- Industrial mines' location (GPS coordinates), start up and closure years, commodity type and production
- Intensively used in the literature
  [Aragon and Rud (2016), Berman, Couttenier et al. (2017), Kotsadam and Tolonen (2016), Tolonen (2018, 2019), Von der Goltz and Barnwal (2019), Mamo, Moradi et al. (2019)]

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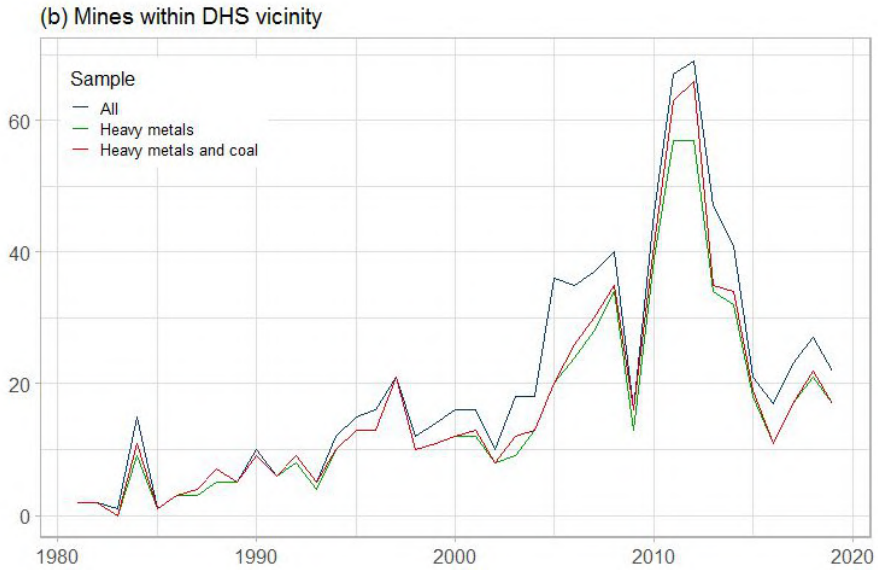
→ 3,815 industrial mines in Africa

→ 2,016 within 100km of a DHS Cluster

→ **Handwork :** 278 had information on start and closure years, we hand-checked 1,738 mines using online research, aerial and satellite images, information from company's website and activity report

→ Mining site image

Mining in Africa



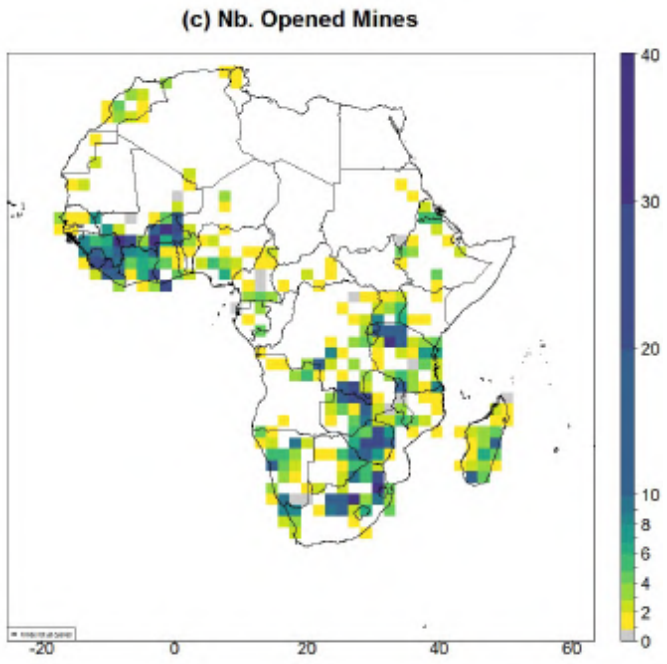
→ Spatial variation of opened mines within Africa

→ Temporal variation Map Graph

→ Focus on heavy metals (results robust when including all metals)
List of heavy metals

→ Foreign investments in Africa increased in the 2000s with the increase of commodity prices

→ Mine openings follow the same pattern as industrial metal prices



Demographic and Health Surveys (DHS)

- (Repeated) cross-sectional surveys, 1986-2018, 26 out of 54 African countries (with at least 2 waves). DHS Waves
- Outcomes of interest : 12 and 24 months mortality. Focus on children under 5 years old Desc. table

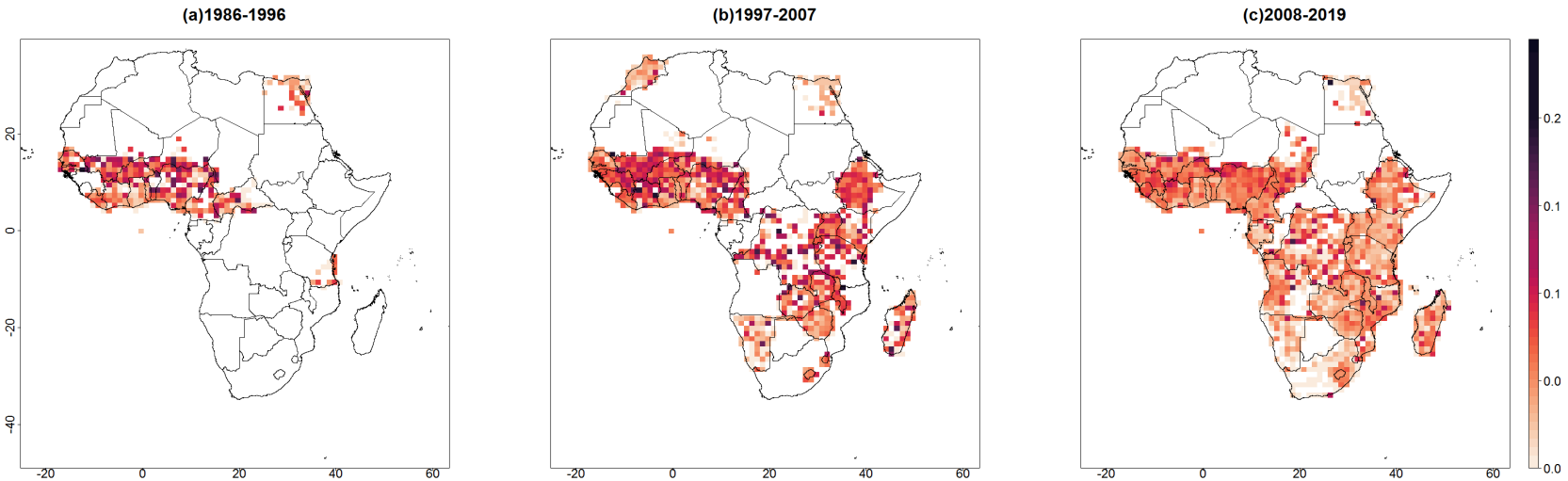


Figure – Spatial variation of 24-month mortality rates

12-month MR spatial sariation

HydroBASINS from HydroSHEDS

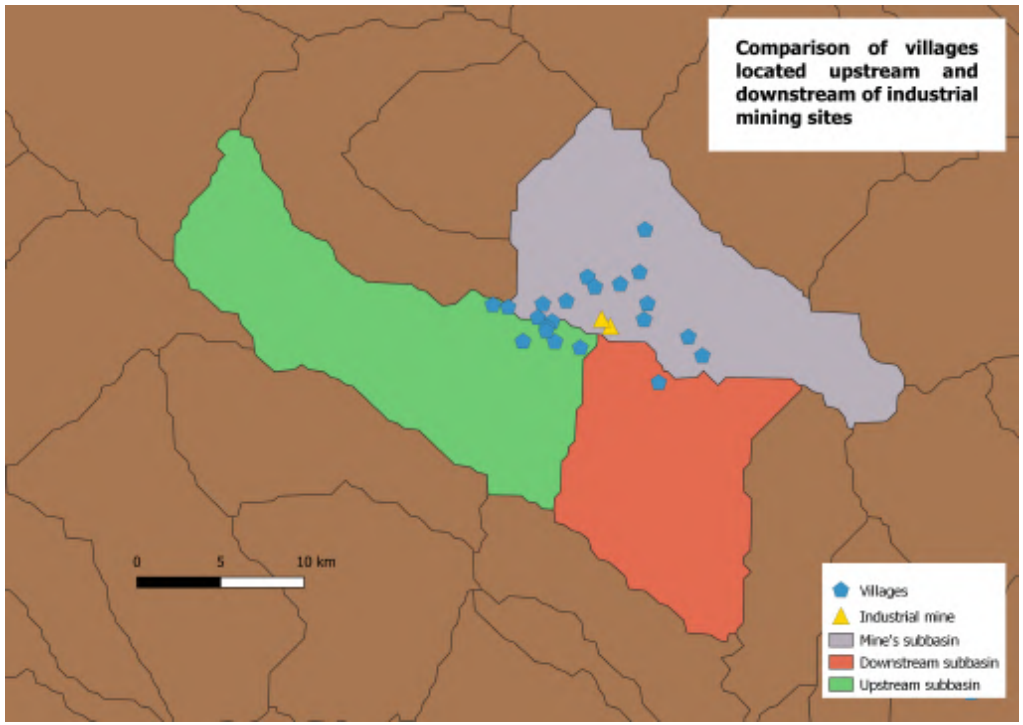
- Subdivides water basins into multiple tributary basins according to the concept of Pfafstetter
- Up- and downstream connectivity of each subbasin
- Finest level : average area of 100 km^2

Comparative advantages

→ Take into account groundwater

→ DEM and topography to rivers is not obvious

→ Deal with DHS random reshuffling



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Matching strategy

- **Challenges**
  - Relying on distance to the closest mine introduces bias : endogeneous matching with unbalanced samples

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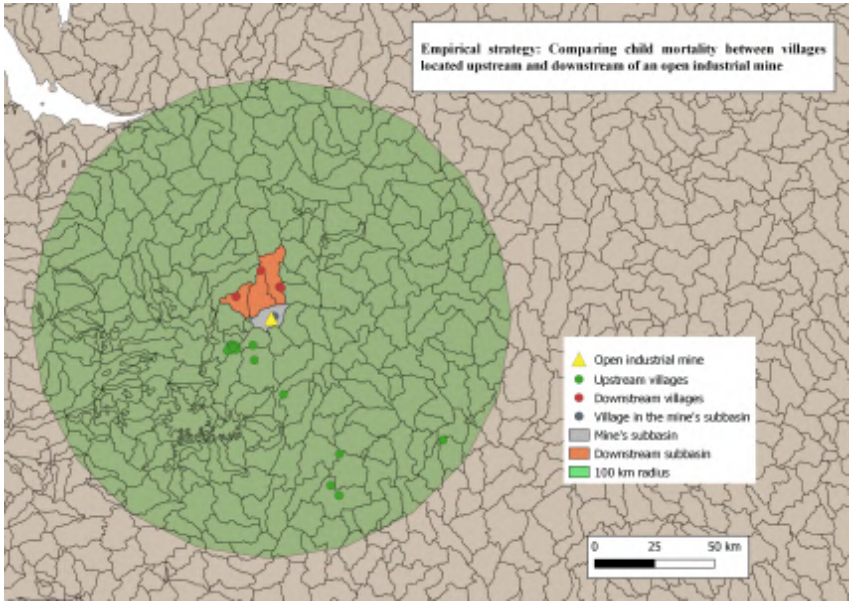
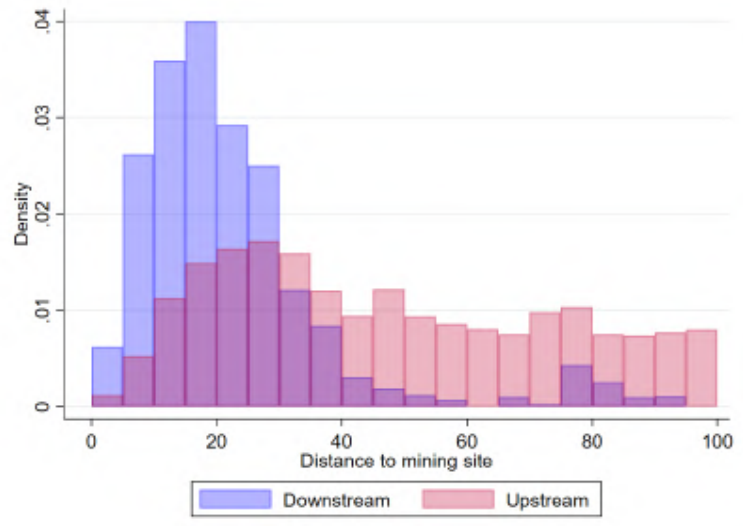
- **Challenges**
  - Relying on distance to the closest mine introduces bias : endogeneous matching with unbalanced samples
- **Main contribution**
  - Matching strategy based on the DHS cluster's topographic position relative to the mine
  - Conservative matching strategy (include only up and down)
  - Difference in the distribution of distance to mine : results robust to changes in buffers (up to 30km)





$$\begin{aligned} Death_{i,v,c,m,SB} =& \alpha_0 + \alpha_1 Opened_{b,i,v} + \alpha_2 Downstream_{v,SB} \\ &+ \alpha_3 Opened_{b,i,v} \times Downstream_{v,SB} + \alpha_4 X_i \\ &+ \gamma_S B + \gamma_{SB-trend} + \gamma_{c,b} + \epsilon_v \end{aligned} \tag{1}$$

- $Death_{i,v,c,d} =$

$$\begin{cases} 1 \text{ if child } i \text{ died before 12 months and [interview date - birth date]} \geq 12 \text{ months} \\ 0 \text{ if child } i \text{ is alive after 12 months and [interview date - birth date]} \geq 12 \text{ months} \\ \text{NA if child } i\text{'s [interview date - birth date]} < 12 \text{ months} \end{cases}$$

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- X_i a vector of child and mother level controls (mother's age, age square, years of education, urban residency).
- γ_{SB} subbasin fixed-effects, $\gamma_{SB-trend}$ subbasin linear birthyear trends and $\gamma_{c,birthyear}$ country-birthyear fixed-effects.

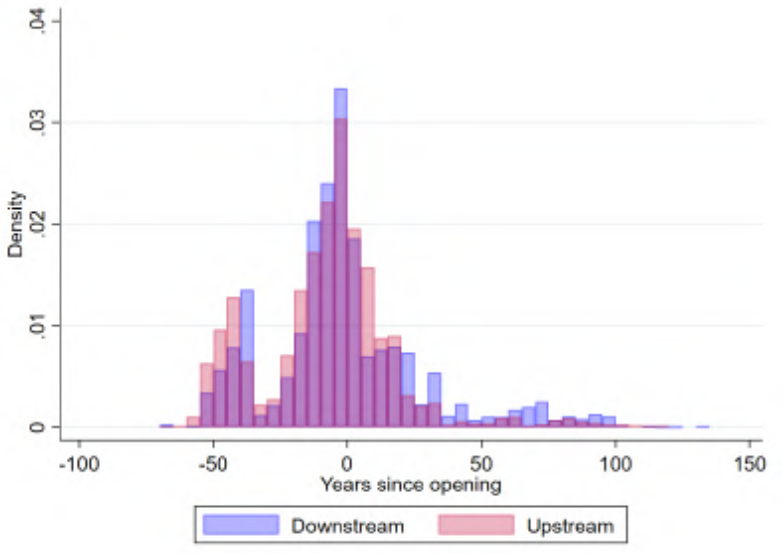
Outline

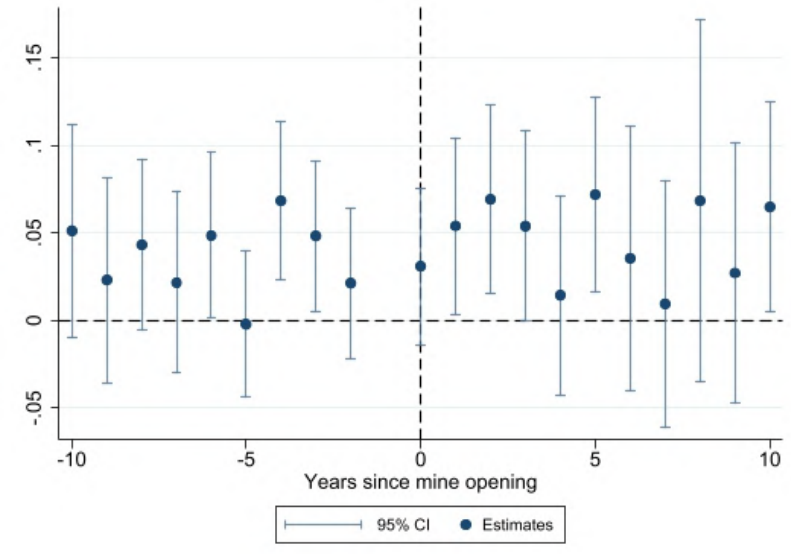
Main results : indirect evidence of water pollution

	Death <12m		Death < 24m	
	All	Drop investment phase [t-1 ;t-3]	All	Drop investment phase [t-1 ;t-3]
	(1)	(2)	(3)	(4)
Downstream×Open	**0.000727**	**0.00967**	**0.0229****	**0.0273****
	[0.00756]	**[0.00866]**	**[0.00985]**	**[0.0109]**
Downstream	-0.0140**	-0.0201***	-0.0174***	-0.0197***
	[0.00612]	[0.00668]	[0.00673]	[0.00736]
Open	0.00707	0.00171	0.00213	-0.00727
	[0.00526]	[0.00647]	[0.00715]	[0.00905]
Birth order number	0.00371***	0.00357***	0.00488***	0.00477***
	[0.000745]	[0.000788]	[0.000918]	[0.000972]
Mother's age	-0.0108***	-0.0108***	-0.0126***	-0.0125***
	[0.00117]	[0.00125]	[0.00152]	[0.00163]
Mother's age square	0.000151***	0.000151***	0.000167***	0.000164***
	[0.0000185]	[0.0000196]	[0.0000237]	[0.0000252]
Years edu.	-0.00134***	-0.00128***	-0.00174***	-0.00183***
	[0.000287]	[0.000307]	[0.000365]	[0.000390]
Urban	-0.00628**	-0.00696**	-0.0121***	-0.0142***
	[0.00285]	[0.00307]	[0.00356]	[0.00381]
N	82571	75076	60814	55218
R2	0.0264	0.0278	0.0365	0.0385
Outcome Mean	0.0652	0.0666	0.0851	0.0873
Outcome Mean - Downstream	0.0657	0.0662	0.0887	0.090
Outcome Mean - Upstream	0.0650	0.0666	0.0844	0.0868

$\longrightarrow$ Being downstream of a mine opening increases by 2.3 p.p. the 24-month mortality rate (27% increase) Parallel trends Balance Table

Dynamic impact - event study





→ Evidence of detrimental effects on local environment during the investment phase

→ Increase of under 24-month mortality rate up to 3 years after a mine opens

→ Work in progress : delay in the positive externalities or household adaptation ?

Heterogeneity analysis

- Water and health access
  - Results robust when controlling for access to piped water and visit to health care facilities Table
- Mine's characteristics
  - Results robust when controlling for country of ownership and mine type
  → Effects driven by foreign and open-pit mines (the most numerous) Table
  - Results robusts when controlling for different commodity types Table Graphs

Heterogeneity analysis : focus on migration

- Households' place of residency and migration status
  - → In-migration and urbanisation within downstream ? Balancing tests
  - → Stronger effects among rural households
  - → Robust results when controlling for in-migration Table
  - → Migrants' selection Table

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- **Further work : study out-migration**
  - → Households' composition, women and spouses' occupation, spouses' education, census or migration modules data

Outline

Robustness checks

- Balanced panel
  - → Comparison of stable groups : switchers *vs* never treated (pure control) *vs* always treated (wrong control) Graph
  - → Robust results : effects mainly identified through switchers Table
- Heterogeneous treatment effects with TWFE (De Chaisemartin and d'Hautfoeuille, 2020) Graph

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- Other tests
  - → Dropping fixed-effects
  - → Dropping country one by one
  - → Sensitivity to manual work

Outline

Conclusion

Contributions

- → Build the most complete database on industrial mine opening in Africa, increased external validity of result and wider heterogeneity analysis
- → Empirical evidence of the effects of mining-induced water pollution on child mortality
  - → Being downstream of a mine opening increases by 27% the 24-month mortality rate

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Next steps

- → Difference between surface *vs* groundwater pollution : triple DiD of subbasins with and without rivers, include geological structure [Taylor (2021)]
- → Effects on other health outcomes : fertility rates, anthropometric measures, stunting, anemia among young children...
- → Key role of mine opening : IV using commodity prices
- → De Chaisemartin and d'Hautfoeuille's (2022) estimator for heterogeneous treatment effects of TWFE with staggered adoption design

Thank you very much for your attention !

Discussion

melanie.gittard@psemail.eu and irene.hu@psemail.eu

Figure – Expansion of the Sierra rutile plant, in Sierra Leone. Satellite images from 1985 and 2020

Source : Google timelapse

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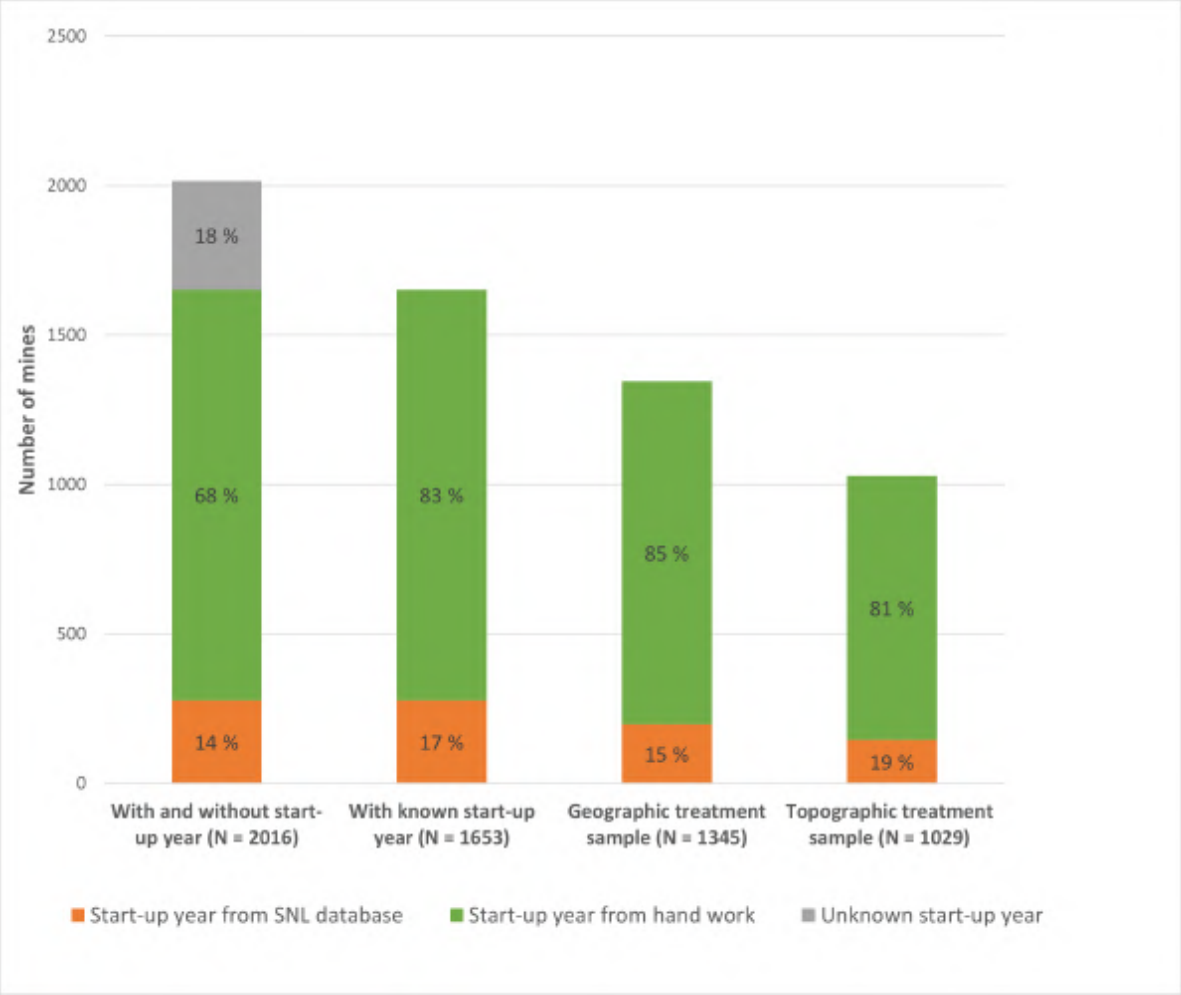

Figure – Description of handwork and industrial mines samples

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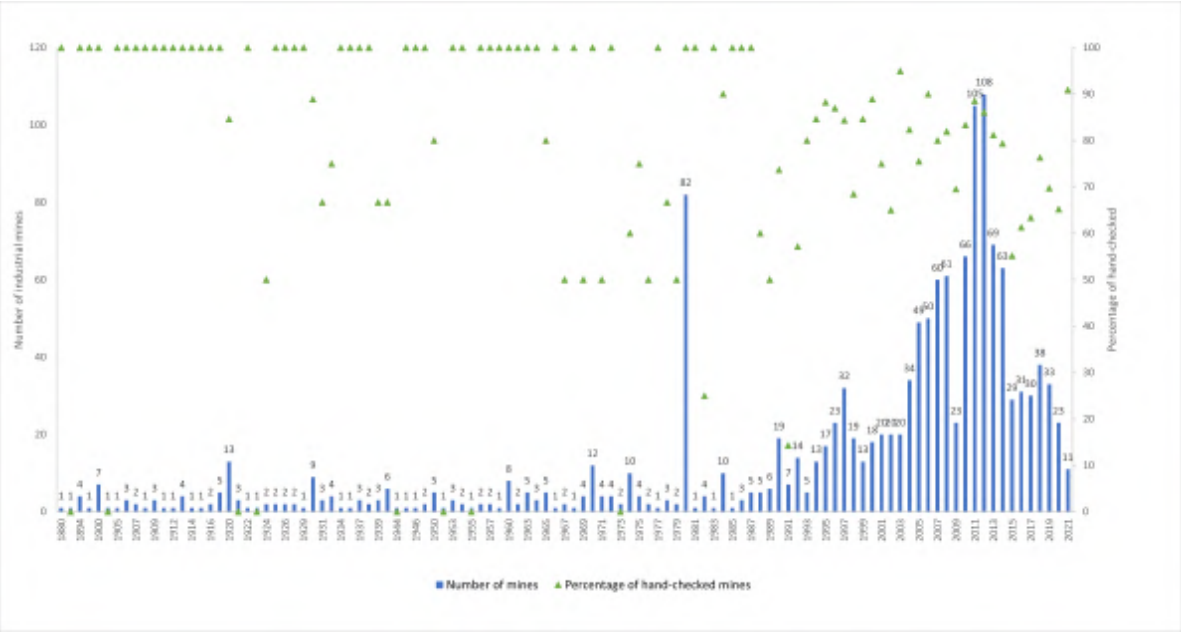

Figure – Mines across start-up years

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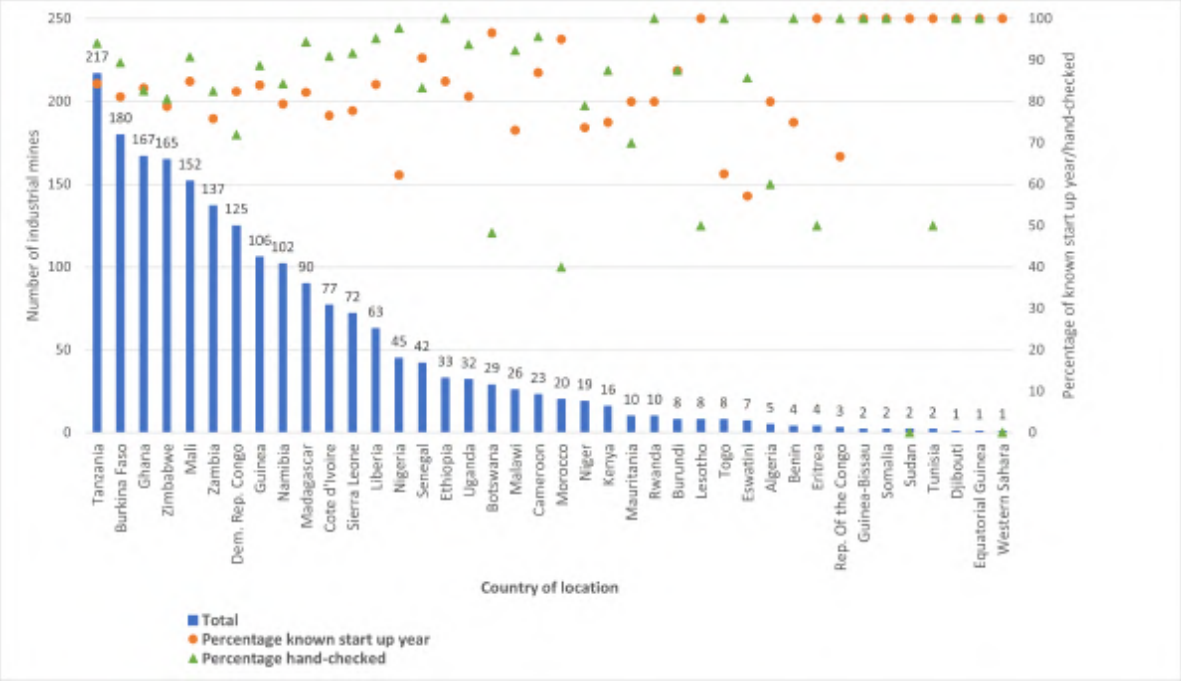

Figure – Mines across country of location

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Countries and DHS surveys included in our paper

Country	Survey Years	#Clusters	#Children<5Y
BF	1993, 1999, 2003, 2010	694	23,846
BJ	2001, 2012, 2017	62	1,911
BU	2010, 2016	317	8,280
CD	2007, 2013	82	5,092
CI	1994, 1998, 2012	196	4,838
CM	1991, 2004, 2011, 2018	90	2,513
ET	2000, 2005, 2010, 2016	100	2,956
GH	1993, 1998, 2003, 2008, 2014	1,217	12,074
GN	1999, 2005, 2012, 2018	360	11,775
KE	2003, 2008, 2014	233	4,130
LB	1986, 2007, 2013	190	7,537
LS	2004, 2009, 2014	336	2,810
MD	1997, 2008	131	3,301
ML	1996, 2001, 2006, 2012, 2018	570	19,147
MW	2000, 2004, 2010, 2015	207	6,651
NG	1990, 2003, 2008, 2013, 2018	105	3,993
NI	1992, 1998	40	1,105
NM	2000, 2006, 2013	138	2,175
RW	2005, 2008, 2010, 2014	713	14,615
SL	2008, 2013	377	13,717
SN	1993, 1997, 2005, 2010, 2012, 2014, 2015, 2016, 2017	363	10,111
TG	1988, 1998, 2013	104	2,187
TZ	1999, 2010, 2015	325	6,866
UG	2000, 2006, 2011, 2016	305	9,031
ZM	2007, 2013, 2018	364	10,966
ZW	1999, 2005, 2010, 2015	468	8,307

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Descriptive statistics of mortality rates

	Mean (1)	SD (2)	Med (3)	Min (4)	Max (5)	N (6)
Living in the matched mine's subbasin						
All children	0.356	0.479	0	0	1	163,056
Children having reached 12months	0.356	0.479	0	0	1	128,317
Children having reached 24 months	0.357	0.479	0	0	1	94,565
Mortality Rates						
Death <12m	0.064	0.245	0	0	1	128,317
Death <12m (outside mine's subbasin)	0.065	0.247	0	0	1	82, 609
Death <24m	0.084	0.278	0	0	1	95,565
Death <24m (outside mine's subbasin)	0.085	0.279	0	0	1	60,849
Death < 1m	0.032	0.176	0	0	1	161,374
Death < 1m (outside mine's subbasin)	0.032	0.176	0	0	1	103,920

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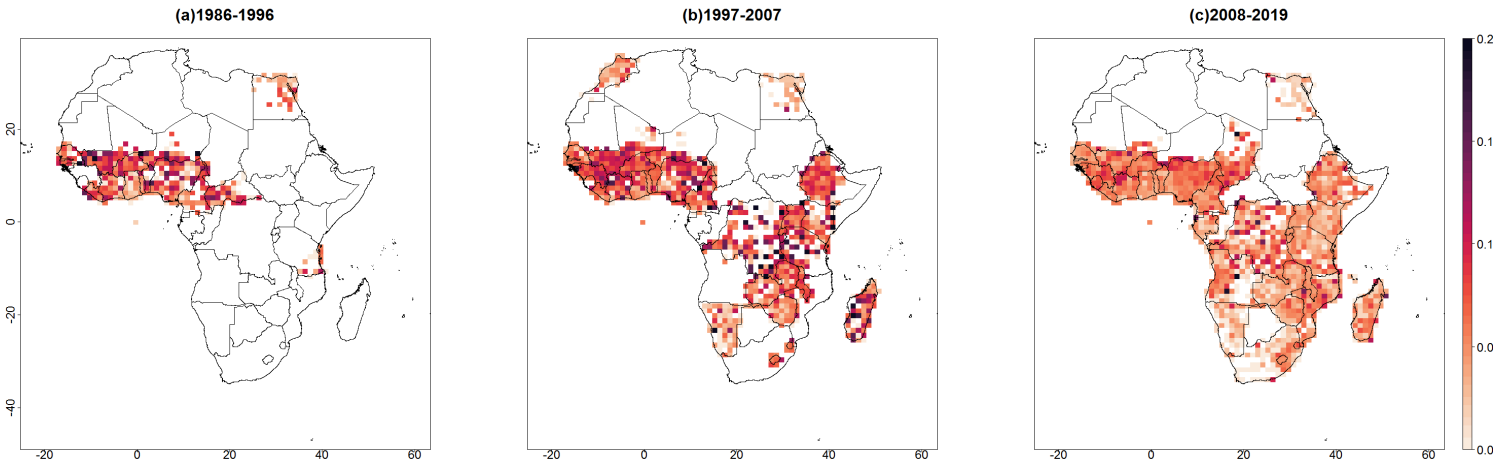

Figure – Spatial variation of 12-month mortality rates per period

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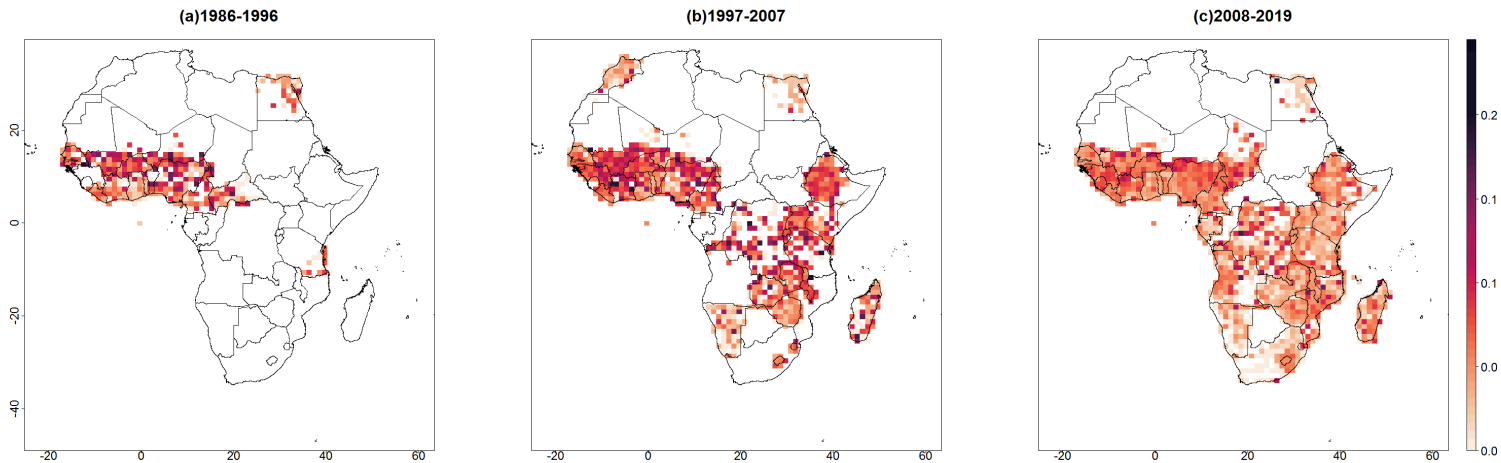

Figure – Spatial variation of 24-month mortality rates per period

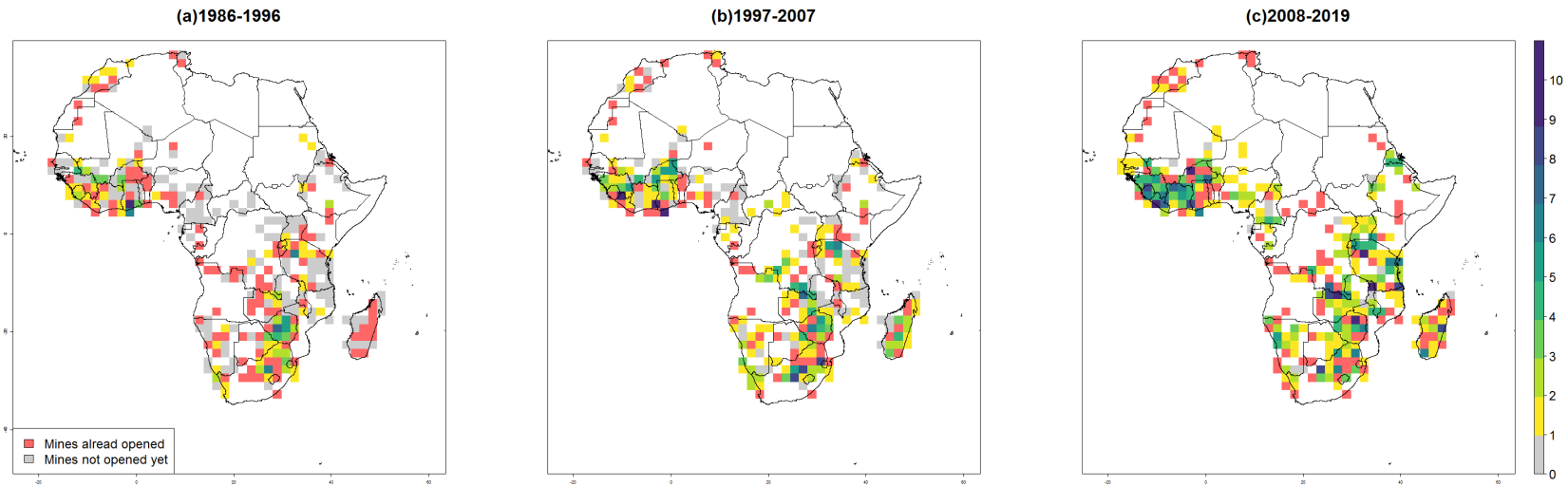

Figure – Spatial and temporal variation of mine opening

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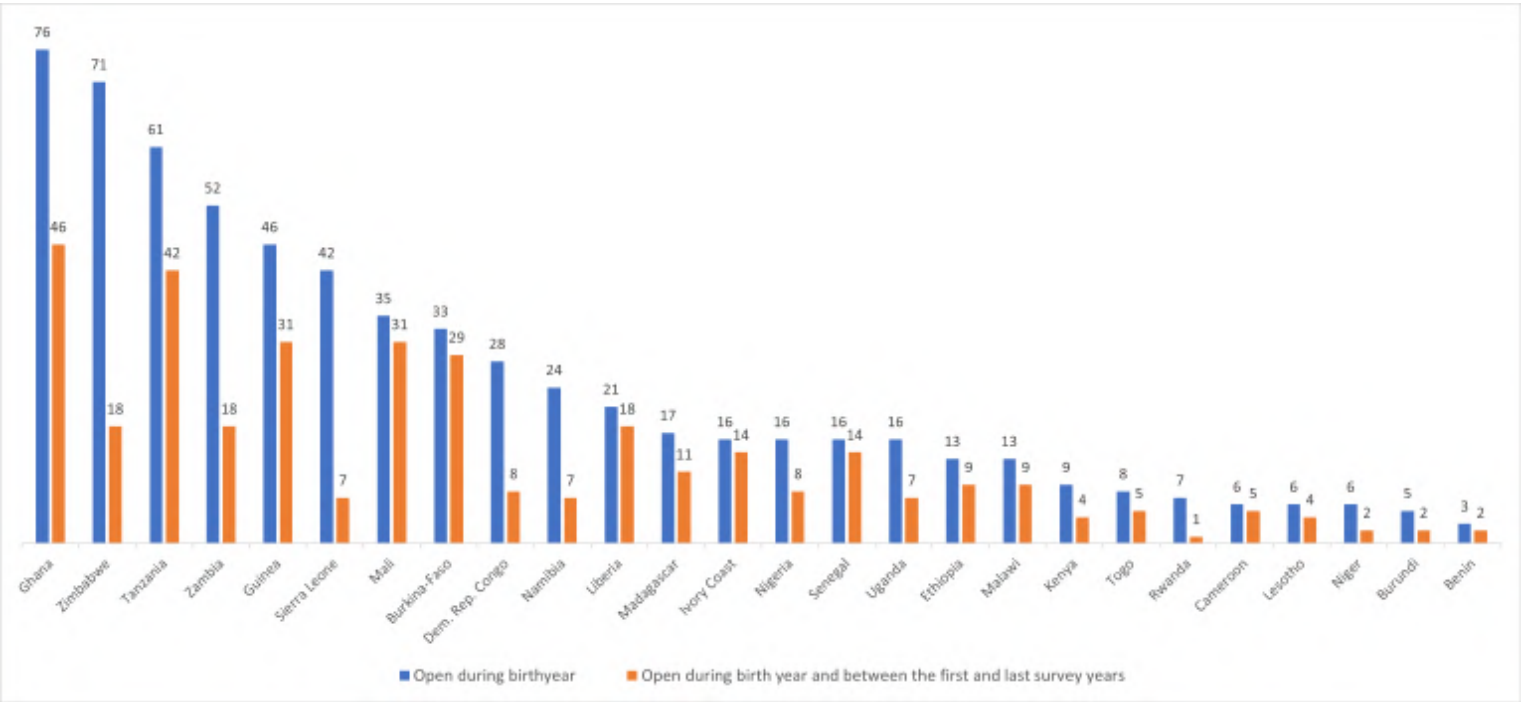
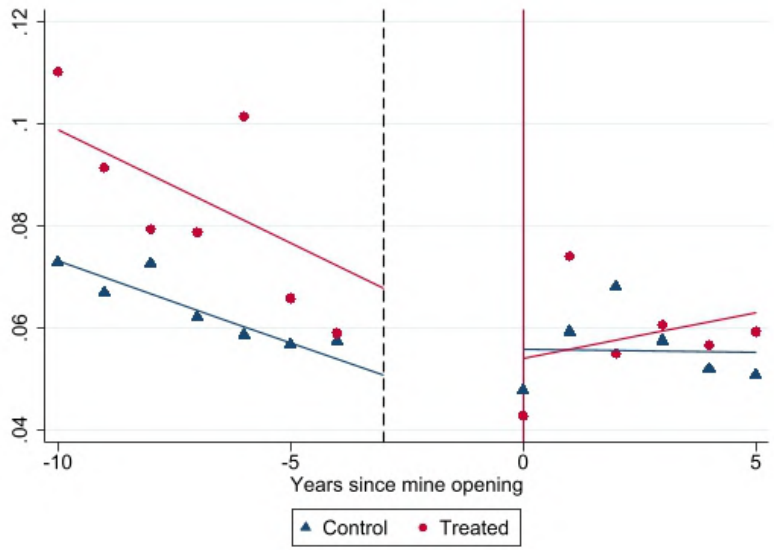
Figure – Number of open mines during birth year and between first and last wave



Metals	Main chemical coumpounds (1)	density (gcm^{-3}) (2)	Nb. Mines (3)	Total Individual Sample (%) (4)
Heavy Metals				
Gold	Gold	19.3	581	41.88
Copper	Copper	8.96	89	5.03
Iron ore	Iron	7.87	54	8.72
U308	Uranium	8.39	36	1.60
Nickel	Nickel	8.9	25	5.06
Platinum	Platinum	21.45	21	0.43
Zinc	Zinc	7.14	19	2.46
Chromite	Iron Chromium	[4.5,5.09]	16	0.57
Ilmenite	titanium	4.6	14	3.67
Lanthanides	Lanthane(57) Lutecium(71)	[6.1,9.8]	13	1.95
Manganese	Manganese	7.21	12	0.62
Tin	Tin	[5.7;7.26]	10	4.87
Cobalt	Cobalt	8.9	7	0.56
Tungsten	Tugsten	19.25	6	1.06
Tantalum	Tantalum	16.69	5	0.15
Vanadium	Vanadium	6.12	4	0.04
Niobium	Niobium	8.57	3	0.39
Heavy Mineral Sands	Zirconium Titanium Tungsten Thorum	[4.5,17.6]	3	0.16
Silver	Silver	10.49	1	0.00
Lead	Lead	11.29	1	0.06
Non-Heavy Metals				
Diamonds	Carbon	3.5	115	11.73
Coal	Carbon Mercury? Arsenic?	1.35	55	2.19
Bauxite	Aluminium	2.79	23	1.94
Graphite	Carbon	2.26	21	0.82
Phosphate	Phosphate	1.83	14	2.78
Lithium	Lithium	0.53	14	0.80



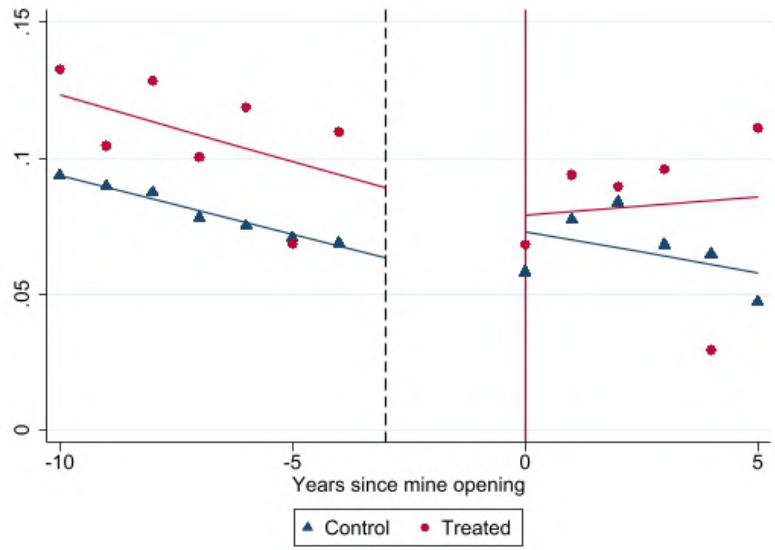


Figure – Linear Trends dropping investment phase, 12-month and 24-month mortality rates

Back to main results

In-migration and rural households

	Death < 24m			
	All	All	Rural Households	Rural Households
	(1)	(2)	(3)	(4)
Downstream×Open	0.0229**	0.0235*	0.0326***	0.0290*
	[0.00985]	[0.0133]	[0.0121]	[0.0163]
Downstream	-0.0174***	-0.0170*	-0.0249***	-0.0262***
	[0.00673]	[0.00958]	[0.00720]	[0.0101]
Open	0.00213	-0.00880	-0.00171	-0.0102
	[0.00715]	[0.0113]	[0.00817]	[0.0129]
Birth order number	0.00488***	0.00327***	0.00629***	0.00447***
	[0.000918]	[0.00125]	[0.00108]	[0.00149]
Mother's age	-0.0126***	-0.0127***	-0.0155***	-0.0159***
	[0.00152]	[0.00203]	[0.00182]	[0.00244]
Mother's age square	0.000167***	0.000171***	0.000202***	0.000211***
	[0.0000237]	[0.0000319]	[0.0000279]	[0.0000376]
Years edu.	-0.00174***	-0.00235***	-0.00139***	-0.00207***
	[0.000365]	[0.000491]	[0.000529]	[0.000724]
Urban	-0.0121***	-0.0147***		
	[0.00356]	[0.00514]		
Migrant		0.00918***		0.00586
N	60814	36377	44999	26745
R2	0.0365	0.0467	0.0432	0.0539
Outcome Mean	0.0851	0.0925	0.0909	0.0997

Back

Piped water as main drinking source and visited health facility in the last 12 months

	Death < 24m			
	(1)	(2)	(3)	(4)
Downstream × Open	0.0229**	0.0230**	0.0187*	0.0188*
	[0.00985]	[0.00984]	[0.0102]	[0.0102]
Downstream	-0.0174***	-0.0175***	-0.0150**	-0.0151**
	[0.00673]	[0.00671]	[0.00692]	[0.00691]
Open	0.00213	0.00196	0.00481	0.00456
	[0.00715]	[0.00716]	[0.00758]	[0.00759]
Birth order number	0.00488***	0.00485***	0.00537***	0.00534***
	[0.000918]	[0.000919]	[0.000967]	[0.000967]
Mother's age	-0.0126***	-0.0126***	-0.0122***	-0.0122***
	[0.00152]	[0.00153]	[0.00160]	[0.00160]
Mother's age square	0.000167***	0.000166***	0.000160***	0.000159***
	[0.0000237]	[0.0000237]	[0.0000250]	[0.0000250]
Years edu.	-0.00174***	-0.00169***	-0.00139***	-0.00132***
	[0.000365]	[0.000368]	[0.000387]	[0.000391]
Urban	-0.0121***	-0.0106***	-0.0100***	-0.00805**
	[0.00356]	[0.00375]	[0.00385]	[0.00406]
Piped Water		-0.00465		-0.00589
		[0.00357]		[0.00381]
Visited Health Facility			-0.00588**	-0.00579**
			[0.00287]	[0.00287]
N	60814	60814	54333	54333

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Robustness : ownership and mining type

	Death < 24m					
	(1)	(2)	(3)	(4)	(5)	(6)
	Ownership control	Domestic owner	Foreign owner	Mining type control	Non open-pit mines	Open-pit mines
Downstream×Open	0.0229**	0.00294	0.0259**	0.0228**	0.0235	0.0691**
	[0.00987]	[0.0220]	[0.0119]	[0.00984]	[0.0176]	[0.0287]
Downstream	-0.0173**	0.0185	-0.0213***	-0.0170**	-0.0101	-0.0326
	[0.00673]	[0.0204]	[0.00722]	[0.00670]	[0.0154]	[0.0210]
Open	0.00251	0.0205	0.00299	0.00271	-0.00970	-0.0356*
	[0.00717]	[0.0240]	[0.00793]	[0.00713]	[0.0151]	[0.0200]
Birth order number	0.00487***	0.00624***	0.00454***	0.00486***	0.00606***	0.00604***
	[0.000918]	[0.00199]	[0.00103]	[0.000918]	[0.00143]	[0.00162]
Mother's age	-0.0126***	-0.00526	-0.0143***	-0.0126***	-0.0134***	-0.0139***
	[0.00152]	[0.00327]	[0.00173]	[0.00152]	[0.00237]	[0.00255]
Mother's age square	0.000166***	0.0000454	0.000195***	0.000167***	0.000177***	0.000181***
	[0.0000237]	[0.0000517]	[0.0000267]	[0.0000237]	[0.0000371]	[0.0000398]
Years edu.	-0.00174***	-0.00217***	-0.00155***	-0.00174***	-0.00152***	-0.00141**
	[0.000365]	[0.000696]	[0.000433]	[0.000365]	[0.000543]	[0.000602]
Urban	-0.0121***	-0.0229**	-0.0103***	-0.0121***	-0.00861	-0.0103*
	[0.00356]	[0.00909]	[0.00391]	[0.00355]	[0.00529]	[0.00604]
Domestic ownership	-0.0364					
	[0.0341]					
Mine type				-0.0469**		
				[0.0203]		
Open Pit					-0.0157	
					[0.0365]	
N	60814	11722	49078	60814	23160	16896
R2	0.0366	0.0481	0.0384	0.0366	0.0454	0.0459
Outcome Mean	0.0851	0.0749	0.0876	0.0851	0.0772	0.0755

Balance table of mortality rates

	Before Mine Opening					After Mine Opening					Within	Within	Within
	Upstream		Downstream		Diff	Upstream		Downstream.		Diff			
	N	Mean /(SD)	N	Mean /(SD)	(4-2) /(p.v)	N	Mean /(SD)	N	Mean /(SD)	(9-7) /(p.v)	(7-2) /(p.v)	(9-4) /(p.v)	(12-11) /(p.v)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Dth<12													
All	44725	0.071	8102	0.073	0.003	24697	0.055	5085	0.054	-0.001	-0.015	-0.019	-0.004
		(0.256)		(0.26)	(0.398)		(0.228)		(0.226)	(0.717)	(0)	(0)	(0.511)
Mines	279		235			204		186					
Dth<24													
All	33688	0.092	6114	0.097	0.005	17465	0.069	3582	0.075	0.006	-0.023	-0.022	0.001
		(0.289)		(0.296)	(0.271)		(0.254)		(0.263)	(0.239)	(0)	(0)	(0.494)
Mines	279		234			192		172					

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Robustness : balanced panel sample

	Death <12m		Death < 24m	
	All	Balanced Panel	All	Balanced Panel
	(1)	(2)	(3)	(4)
Downstream × Open	0.000727	0.0132	0.0229**	0.0305**
	[0.00756]	[0.0123]	[0.00985]	[0.0151]
Downstream	-0.0140**	-0.0170**	-0.0174***	-0.0211**
	[0.00612]	[0.00734]	[0.00673]	[0.00829]
Open	0.00707	0.0136	0.00213	0.0191
	[0.00526]	[0.0222]	[0.00715]	[0.0321]
Birth order number	0.00371***	0.00230	0.00488***	0.00236
	[0.000745]	[0.00157]	[0.000918]	[0.00196]
Mother's age	-0.0108***	-0.0127***	-0.0126***	-0.0150***
	[0.00117]	[0.00276]	[0.00152]	[0.00351]
Mother's age square	0.000151***	0.000187***	0.000167***	0.000209***
	[0.0000185]	[0.00276]	[0.0000237]	[0.0000544]
Years edu.	-0.00134***	-0.00167**	-0.00174***	-0.00188**
	[0.000287]	[0.000729]	[0.000365]	[0.000896]
Urban	-0.00628**	0.00538	-0.0121***	0.00141
	[0.00285]	[0.00557]	[0.00356]	[0.00761]
Constant	0.237***	0.264***	0.296***	0.336***
	[0.0180]	[0.0425]	[0.0238]	[0.0550]
N	82571	17979	60814	13839
R2	0.0264	0.0380	0.0365	0.0482
Outcome Mean	0.0652	0.0661	0.0851	0.0897

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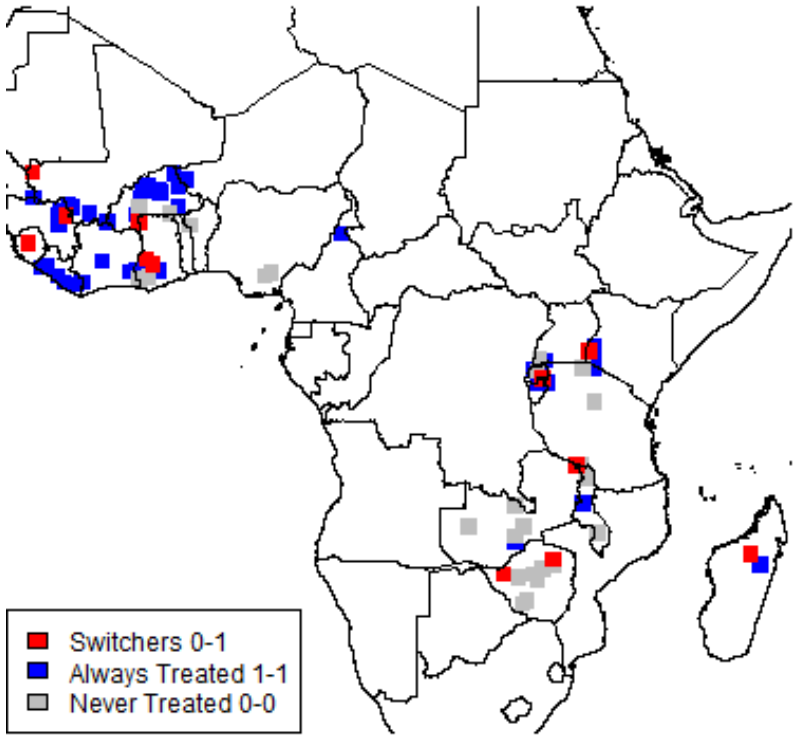

Figure – Balanced panel - group identification

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Balancing tests

	Before Mine Opening					After Mine Opening					Within Up.	Within Dwn.	Within
	Upstream		Downstream		Diff	Upstream		Downstream.		Diff			
	N	Mean /(SD)	N	Mean /(SD)	(4-2) /(p.v)	N	Mean /(SD)	N	Mean /(SD)	(9-7) /(p.v)	(7-2) /(p.v)	(9-4) /(p.v)	(12-11) /(p.v)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Under 24 Children Sample													
Household Characteristics													
% Urban Household													
All	33688	0.272	6114	0.162	-0.11	17465	0.269	3582	0.269	0	-0.003	0.106	**0.11**
		(0.445)		(0.369)	(0)		(0.443)		(0.443)	(0.958)	(0.438)	(0)	**(0)**
Mines	279		234			192		172			92	49	9
Mother Charateristics													
Age													
All	33688	30.185	6114	29.924	-0.26	17465	30.233	3582	29.929	-0.304	0.048	0.005	-0.044
		(6.999)		(6.963)	(0.007)		(6.843)		(7.033)	(0.018)	(0.451)	(0.974)	(0.842)
Years of Education													
All	33688	2.347	6114	3.063	0.716	17465	3.795	3582	4.697	0.902	1.449	1.635	0.186
		(3.528)		(3.794)	(0)		(4.17)		(4.07)	(0)	(0)	(0)	(0.737)
% Migrant													
All	19223	0.602	4148	0.57	-0.032	10533	0.61	2494	0.591	-0.019	0.008	**0.021**	0.013
		(0.489)		(0.495)	(0)		(0.488)		(0.492)	(0.08)	(0.196)	**(0.098)**	(0.655)
Mines	248		186			150		133			61	30	6

Robusness : dropping fixed-effects

	Death < 24m			
	(1)	(2)	(3)	(4)
Downstream × Open	0.0229**	0.0227**	0.0201**	0.0195**
	[0.00985]	[0.00983]	[0.00958]	[0.00953]
Downstream	-0.0174***	-0.0174***	-0.0182***	-0.0178***
	[0.00673]	[0.00671]	[0.00669]	[0.00670]
Open	0.00213	0.00219	0.00345	0.00262
	[0.00715]	[0.00716]	[0.00715]	[0.00708]
Birth order number	0.00488***	0.00482***	0.00480***	0.00479***
	[0.000918]	[0.000917]	[0.000916]	[0.000916]
Mother's age	-0.0126***	-0.0125***	-0.0125***	-0.0125***
	[0.00152]	[0.00152]	[0.00152]	[0.00152]
Mother's age square	0.000167***	0.000166***	0.000166***	0.000165***
	[0.0000237]	[0.0000237]	[0.0000237]	[0.0000237]
Years edu.	-0.00174***	-0.00176***	-0.00176***	-0.00177***
	[0.000365]	[0.000364]	[0.000365]	[0.000364]
Urban	-0.0121***	-0.0147***		
	[0.00356]	[0.00514]		
Constant	-0.0121***	-0.0122***	-0.0120***	-0.0120***
	[0.00356]	[0.00356]	[0.00356]	[0.00356]
Country-Bthyear FE	Yes	Yes	Yes	Yes
SB FE	Yes	Yes	Yes	Yes
SB Bthyear trend	Yes	Yes	Yes	No
Commodity FE	Yes	Yes	No	No
Birthmonth FE	Yes	No	No	No
N	60814	60814	60814	60814
R2	0.0365	0.0362	0.0361	0.0355
Mean	0.0851	0.0851	0.0851	0.0851

Robustness : sensitivity to handwork

	Death < 24m			
	(1)	(2)	(3)	(4)
Downstream × Open	0.0229**	0.0228**	0.0252	0.0249**
	[0.00985]	[0.00984]	[0.0309]	[0.0106]
Downstream	-0.0174***	-0.0176***	-0.0175	-0.0193***
	[0.00673]	[0.00673]	[0.0236]	[0.00703]
Open	0.00213	0.00212	-0.0400	0.00148
	[0.00715]	[0.00715]	[0.0329]	[0.00763]
Birth order number	0.00488***	0.00488***	0.00402*	0.00500***
	[0.000918]	[0.000918]	[0.00233]	[0.00100]
Mother's age	-0.0126***	-0.0126***	-0.0154***	-0.0122***
	[0.00152]	[0.00152]	[0.00421]	[0.00164]
Mother's age square	0.000167***	0.000167***	0.000223***	0.000158***
	[0.0000237]	[0.0000237]	[0.0000682]	[0.0000253]
Years edu.	-0.00174***	-0.00174***	-0.00199***	-0.00161***
	[0.000365]	[0.000365]	[0.000718]	[0.000424]
Urban	-0.0121***	-0.0121***	-0.0126	-0.0120***
	[0.00356]	[0.00356]	[0.0108]	[0.00381]
Hand Checked		0.0463		
		[0.0330]		
Constant	0.296***	0.257***	0.340***	0.292***
	[0.0238]	[0.0372]	[0.0651]	[0.0255]
N	60814	60814	8695	52112
r2	0.0365	0.0366	0.0571	0.0380
Outcome Mean	0.0851	0.0851	0.0781	0.0863

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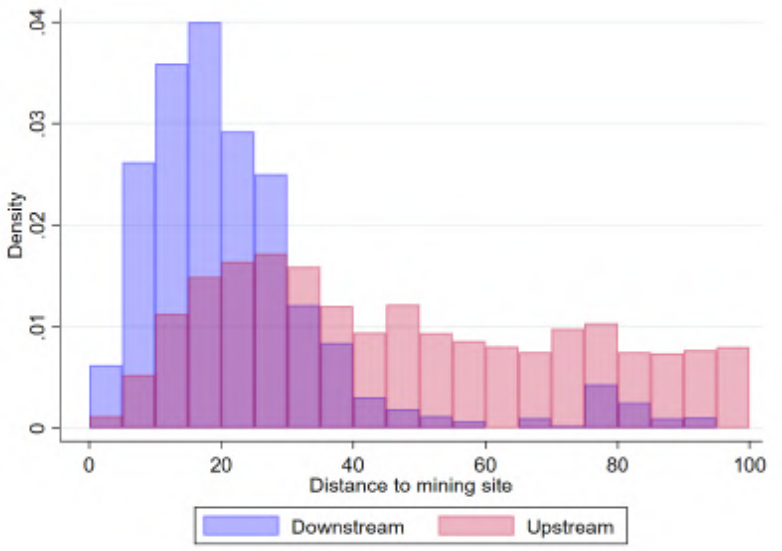
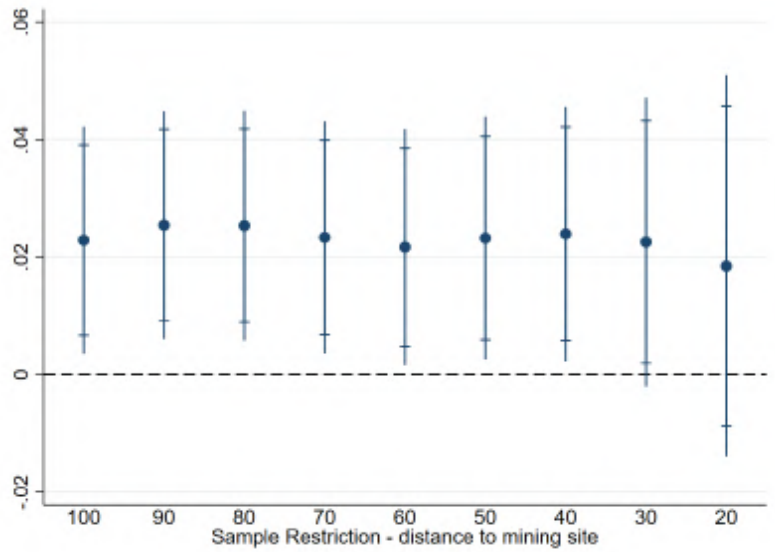
Robustness : across distance brackets





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Robustness : across commodity types

	Death < 24m		
	All Mines	Heavy Metals without Coal Mines	Gold Mines
	(1)	(2)	(3)
Downstream × Open	0.0179*	0.0208**	0.00789
	[0.00947]	[0.00966]	[0.0168]
Downstream	-0.0120*	-0.0181***	-0.0171*
	[0.00673]	[0.00672]	[0.00875]
Open	0.00186	0.00274	0.00514
	[0.00600]	[0.00706]	[0.0103]
Birth order number	0.00522***	0.00470***	0.00588***
	[0.000819]	[0.000903]	[0.00140]
Mother's age	-0.0123***	-0.0124***	-0.0155***
	[0.00136]	[0.00150]	[0.00233]
Mother's age square	0.000163***	0.000164***	0.000207***
	[0.0000212]	[0.0000234]	[0.0000362]
Years edu.	-0.00173***	-0.00170***	-0.00148**
	[0.000325]	[0.000359]	[0.000648]
Urban	-0.0121***	-0.0123***	-0.0139**
	[0.00312]	[0.00351]	[0.00558]
N	75512	62277	29835
r2	0.0355	0.0371	0.0414
Outcome Mean	0.0832	0.0843	0.0967

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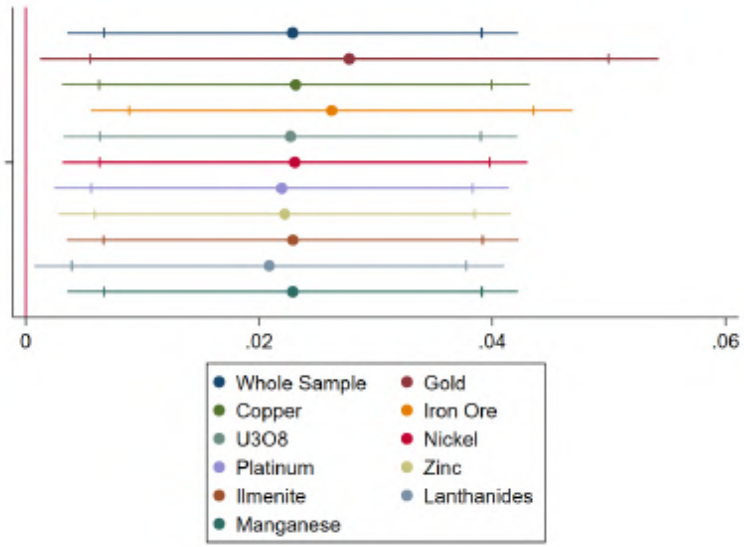
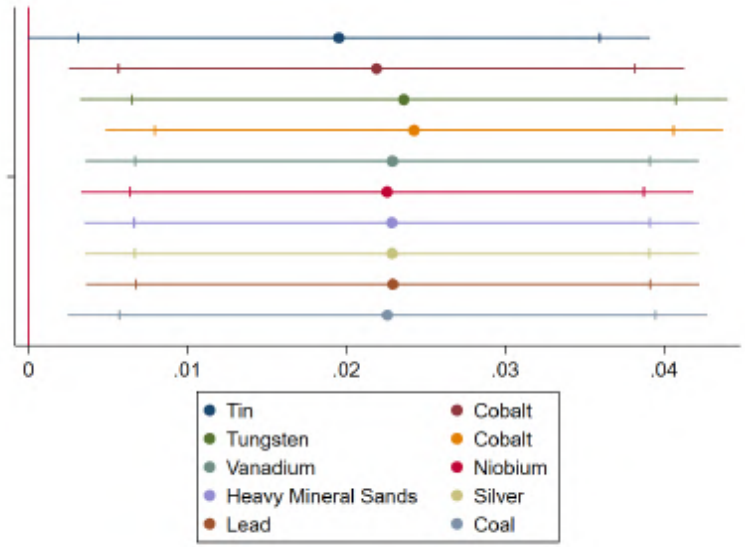
Dropping commodity type one by one





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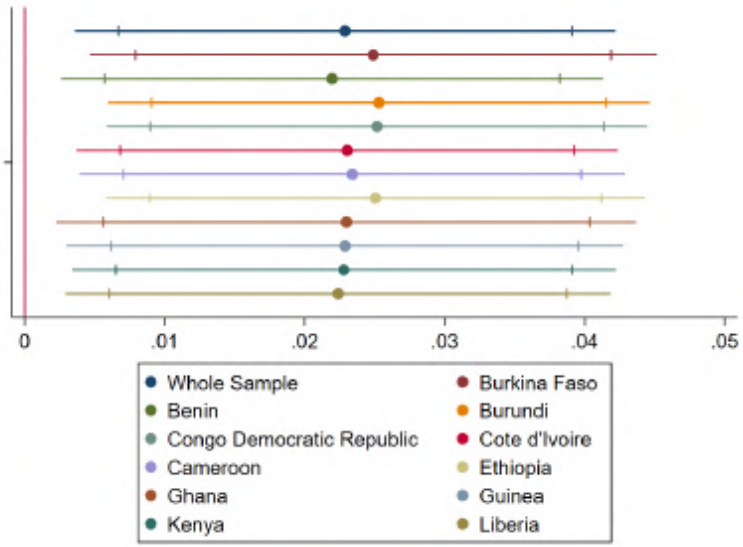
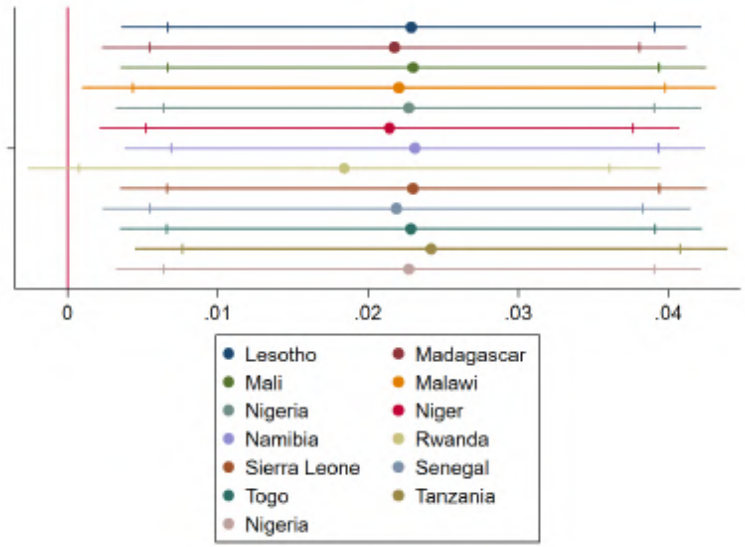
Dropping country one by one





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Heterogeneity : focus on migration

	Migrant	Death < 24m	
		Non-migrant sample	Migrant sample
	(1)	(2)	(3)
Downstream × Open	0.0325	0.0284	0.0253
	[0.0342]	[0.0228]	[0.0174]
Downstream	-0.0293	-0.0192	-0.0182
	[0.0269]	[0.0160]	[0.0123]
Open	-0.0161	-0.00201	-0.0108
	[0.0216]	[0.0180]	[0.0142]
Birth order number	0.000695	0.00329*	0.00258
	[0.00203]	[0.00197]	[0.00163]
Mother's age	0.0148***	-0.00962***	-0.0146***
	[0.00319]	[0.00306]	[0.00281]
Mother's age square	-0.000247***	0.000132***	0.000195***
	[0.0000498]	[0.0000479]	[0.0000440]
Years edu.	0.00227**	-0.00153**	-0.00295***
	[0.00105]	[0.000756]	[0.000649]
Urban	0.0274**	-0.0258***	-0.0104*
	[0.0120]	[0.00820]	[0.00628]
N	36377	14518	21807
R2	0.166	0.0743	0.0599
Outcome Mean	0.600	0.0870	0.0962

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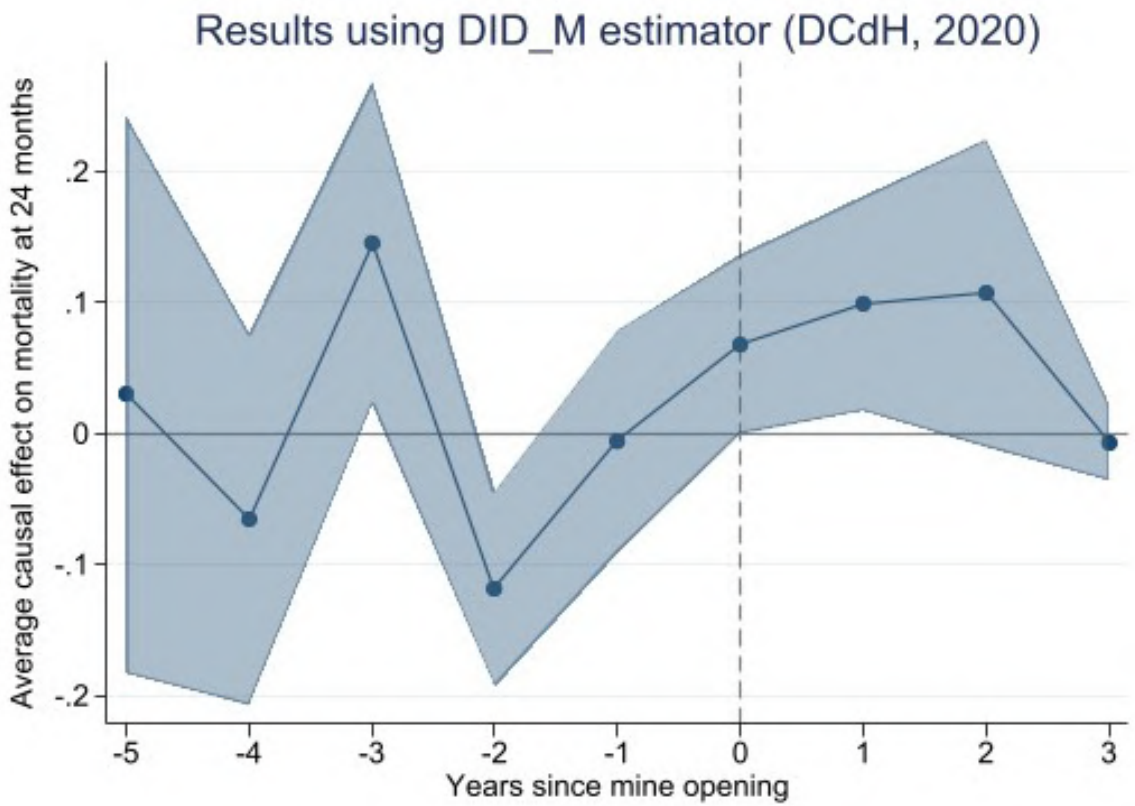
De Chaisemartin and d'Haultefoeuille (2020) *did_multiplegt* Stata command



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Replication exercice : geographical distance treatment

$$
\begin{aligned}
Death_{i,v,c,m,SB} =& \alpha_{\mathbf{0}} + \alpha_{\mathbf{1}} Opened_{birthyear,i,v} + \alpha_{\mathbf{2}} MineDeposit_{[\mathbf{0};\mathbf{10}km],v} \\
&+ \alpha_{\mathbf{3}} Opened_{birthyear,i,v} \times MineDeposit_{[\mathbf{0};\mathbf{10}km],v} + \alpha_{\mathbf{4}} X_i \\
&\gamma_d + \gamma_{d-bthtrend} + \gamma_{c,birthyear} + \epsilon_v
\end{aligned} \tag{2}
$$

$Opened_{birthyear,v} =$

$$
\begin{cases}
1 \text{ if mine has opened before the birthyear of child } i\text{, living within 100 km} \\
0 \text{ if the mine has opened after the birthyear, living within 100km.}
\end{cases}
$$

$MineDeposit_{[0;10km],v} =$

$$
\begin{cases}
1 \text{ if child } i \text{ is living DHS cluster } v \text{ within } [0;10km] \text{ from the } \textbf{closest} \text{ mine} \\
0 \text{ if child } i \text{ is living within } [10;100km] \text{ from the } \textbf{closest} \text{ mine}
\end{cases}
$$

X_i a vector of child/mother level controls (mother's age and age square, years of education, urban status)/ γ_d is a district fixed effect, $\gamma_{d-bthtrend}$ a district birthyear linear trend and $\gamma_{c,birthyear}$ a country-birthyear fixed effect.

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Exact replication of Tolonen (2018)

Dependent variable	Infant mortality first 12 months			
Sample :	Children	Children drop spillover	Boys	Girls
	(1)	(2)	(3)	(4)
Industrial × mine deposit (at birth)	-0.0472**	-0.0474*	-0.0289	-0.0781***
	[0.0230]	[0.0260]	[0.0320]	[0.0301]
Mine deposit [0 ;10km]	0.0392**	0.0546***	0.0517**	0.0561**
	[0.0169]	[0.0195]	[0.0229]	[0.0231]
Mother's age	-0.0145***	-0.0154***	-0.0155***	-0.0152***
	[0.00190]	[0.00210]	[0.00274]	[0.00297]
Mothers's age × Mother's age	0.000222***	0.000236***	0.000223***	0.000245***
	[0.0000302]	[0.0000335]	[0.0000435]	[0.0000475]
Years edu.	-0.00214***	-0.00230***	-0.00272***	-0.00184**
	[0.000489]	[0.000547]	[0.000827]	[0.000760]
$\text{Urban}_h h$	-0.0125***	-0.0120**	-0.00710	-0.0183***
	[0.00428]	[0.00480]	[0.00687]	[0.00659]
Birth-month FE	Yes	Yes	Yes	Yes
Country birth year FE	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
District BirthYear trend	Yes	Yes	Yes	Yes
Drop10-30 km away	No	Yes	Yes	Yes
Drop investment phase	No	Yes	Yes	Yes
Mean of outcome	0.102	0.104	0.110	0.099
Mean(treatment, pre-treatment)	0.154	0.163	0.173	0.153
Observations	41902	34228	17534	16694

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Extended sample with Tolonen's (2018) estimation

	Infant mortality first 12 months							
	All		Drop spillover		Boys		Girls	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Indus. × deposit	-0.00259	-0.00823**	-0.00189	-0.00575	0.00250	-0.00302	-0.00513	-0.00807
	[0.00329]	[0.00418]	[0.00407]	[0.00537]	[0.00570]	[0.00764]	[0.00522]	[0.00674]
Deposit	0.00130	0.00374	0.00103	-0.000128	0.00632	0.0113	-0.00366	-0.0109*
	[0.00252]	[0.00317]	[0.00392]	[0.00500]	[0.00546]	[0.00708]	[0.00513]	[0.00628]
Birth order	0.00389***	0.00315***	0.00360***	0.00320***	0.00349***	0.00304***	0.00382***	0.00356***
	[0.000345]	[0.000428]	[0.000423]	[0.000518]	[0.000606]	[0.000742]	[0.000549]	[0.000671]
Mother's age	-0.0105***	-0.0107***	-0.0102***	-0.0110***	-0.0116***	-0.0128***	-0.00884***	-0.00924***
	[0.000541]	[0.000668]	[0.000669]	[0.000824]	[0.000953]	[0.00119]	[0.000903]	[0.00111]
agesquare	0.000147***	0.000151***	0.000142***	0.000156***	0.000163***	0.000183***	0.000121***	0.000127***
	[0.00000853]	[0.0000106]	[0.0000106]	[0.0000131]	[0.0000150]	[0.0000187]	[0.0000142]	[0.0000175]
Years edu.	-0.000877***	-0.00103***	-0.000874***	-0.00101***	-0.000881***	-0.00103***	-0.000873***	-0.000968***
	[0.000135]	[0.000167]	[0.000164]	[0.000200]	[0.000238]	[0.000290]	[0.000216]	[0.000265]
Urban	-0.00610***	-0.00725***	-0.00708***	-0.00906***	-0.00825***	-0.0111***	-0.00563**	-0.00622**
	[0.00135]	[0.00172]	[0.00169]	[0.00214]	[0.00235]	[0.00297]	[0.00227]	[0.00289]
migrant		0.00543***		0.00509***		0.00255		0.00754***
		[0.00120]		[0.00145]		[0.00208]		[0.00196]
Birth-month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ctry-bthyr FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dist-bthyr trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Drop10-30 km	No	No	Yes	Yes	No	No	No	No
Drop t-2	No	No	Yes	Yes	No	No	No	No
N	359219	243645	236573	165202	119860	83570	116696	81601

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