

The Effects of Early-Life Exposure to Pollution on Children's Human Capital Formation: the Case of Indonesia

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Motivation

- Pollution affects morbidity and mortality 3.7 million deaths in 2012 (WHO)
- How would early life exposure to air pollution in developing countries affect children?
- Still developing, vulnerable respiratory system
- Air pollution is a negative health shock
- Limited resources to mitigate effects of negative shocks
- Effects of early life health shocks often persist

Our paper

- Indonesia experienced one of the worst fires in 1997
- Effects were widespread: morbidity and mortality effects (Frankenberg et al 2005, Jayachandran 2009)
- How does early-life exposure to forest fires affect surviving children's human capital formation?
- Short-term and medium-term effects

Outline

- ① Background and literature:
 - Short term and long term effects
 - Indonesian forest fires
- ② Data
- ③ Estimation
- ④ Preliminary results
- ⑤ Next steps

Framework

- Prenatal and postnatal periods as sensitive stage of development (Barker 1995)
- Negative shocks in early years can impair development and skill formation
- Past skills influence both future skills and investments (Heckman and Cunha 2007)
- Evidence on pollution and human capital outcomes has relied on natural experiments (Currie et al., 2013 for a review)

Link between pollution and child endowment

- Precise mechanism between air pollution and cognitive achievement unclear
- Hypothesized channel:
- CO crosses placental barrier
- CO exposure affects outcomes through cardiovascular and respiratory function

Empirical evidence

- Exposure to CO in utero and early childhood linked to lower pulmonary function (Mortimer et al 2008, Neidell 2004, Plopper and Fanucchi 2000)
- Air pollution in utero increases the neonatal and infant mortality (Currie et al., 2013 for a review)
- Evidence from 1997 Indonesian fire consistent with literature

Empirical evidence

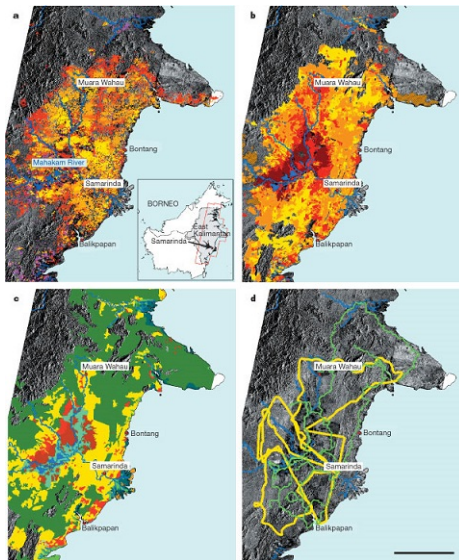
- More limited evidence on early life pollution and long-term human capital outcomes:
- IQ scores, education and earnings (Almond et al., 2009; Bharadwaj et al., 2013; Currie et al., 2013b; Peet, 2014; and Black et al., 2013)
- Exposure in the first year of life associated with lasting negative effects in adulthood (Currie et al., 2013)

The 1997 Fire

- Slash and burn common in Indonesia
- El Nino causes drier condition, fires burn more intensely
- El Nino between August and November 1997, affected 2-3% of Indonesia's land area
- Levels of PM10 > 2000 micrograms/cubic meter in affected areas in September (Heil et al 2001)

Endogenous exposure of pollution

- Selection into high pollution area
- Intensity of the fire was unexpected because of El Nino
- State of emergency declared
- Natural experiment to study the effect of air pollution



Source: Siegert et al 2001

Related work

- Jayachandran (2009) used data from the 2000 census combined with aerosol index from NASA's Earth Probe Total Ozone Mapping Spectrometer (TOMS)
- Exposure to 1997 fires led to a 1.2 percent decline in birth cohort size
- No significant gender effect
- Larger effects in poorer districts

Related work

- Frankenberg et al. (2005) used the IFLS and TOMS
- Worse adult health outcomes:
- Self-reported general health status, respiratory problems
- This paper: effects of exposure on surviving children

Data: IFLS

- 7,224 panel households in 1993 in 13 provinces
- Representative of about 83% of population, including provinces affected by fires:
- North Sumatra, West Sumatra, South Sumatra, Lampung, South Kalimantan
- Subsequent waves in 1997, 2000, 2007
- Split-off households included

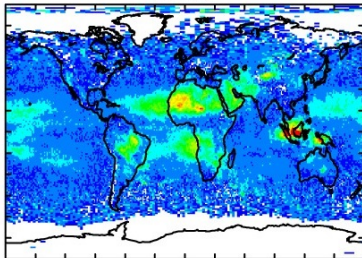
Data

- Detailed information on children: prenatal care, birth weight (mother's recall), cognitive test (in 2007)
- Anthropometric measures on survey years: height, weight, lung function (>9 yrs)
- Mother characteristics: education, age at delivery (based on mother and child's date of birth)
- Household characteristics: per capita expenditure quintile, household size, urban residence
- Sample restricted to children born between 1995 and 2000

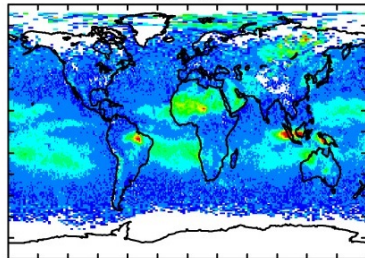
TOMS Aerosol index

- Daily aerosol measures from July 1996-December 2005
- 1 degree latitude and 1.25 longitude grid
- Index ranges from 0 to 5
- Aerosol index correlated with pollution measures (Ostermann et al 2001)
- Aerosol index > 1.5 for ≥ 3 days (Frankenberg et al. 2005)
- Match IFLS district centroid to monthly average of aerosol index

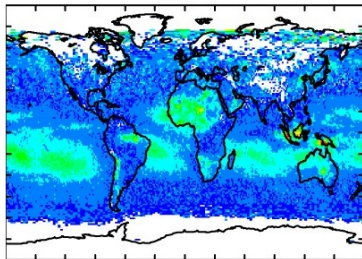
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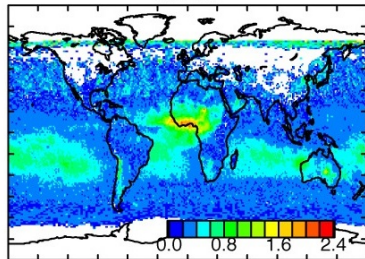
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Variables of interest

- Separate exposure in utero, first year of life, second year of life
- Short-term outcomes: difficulty breathing in 1997, height for age and stunting in 2000
- Medium-term outcomes: height, test scores, lung capacity in 2007

Estimation strategy

- Exploit timing of the forest fires and geographic variation of the location
- August to November 1997 in Sumatra and Borneo
- Information on month and year of birth, district of birth
- Indicator for exposure in development stages: in utero, first year (0-12 mo), second year (13-24 mo)

Estimation strategy

$$Y_{imyd} = \sum_{k=utero}^{age2} \delta_k Exp_k_{imyd} + \beta X_{ibd} + \theta_m + \gamma_y + \mu_d + \epsilon_{imyd}$$

- Y is the outcome for child i , born in month m , year y , district d
- $Exp_k = 1$ if child was exposed in utero, age 1, age 2
- Month, year, district FE included
- Mother and household characteristics included
- SE clustered at community level (enumeration area)

Summary statistics

	Non-exposed	Exposed
Height for age	-1.478	-1.961
(wave 3)	(1.631)	(1.122)
Stunted	0.384	0.464
(wave 3)	(0.486)	(0.500)
Height in cm	128.114	132.902
(wave 4)	(11.784)	(9.680)
Any respiratory problem	0.044	0.059
(wave 2)	(0.206)	(0.236)
Lung capacity (log)	5.337	5.321
(wave 4)	(0.287)	(0.246)
Test score (wave 4)	0.694	0.721
(fraction correct)	(0.176)	(0.171)
Cognitive test score (wave 4)	0.731	0.758
(fraction correct)	(0.199)	(0.192)
Math test score (wave 4)	0.604	0.631
(fraction correct)	(0.237)	(0.223)
N	3,519	256

Balance test

VARIABLES	(1) Male child	(2) HH size	(3) Poor	(4) Urban	(5) Mother's edu	(6) Land
In-utero	0.0263 (0.0607)	-0.162 (0.321)	-0.0667 (0.0607)	-0.0690 (0.0611)	0.0124 (0.0407)	-0.0475 (0.0395)
Year 1	-0.0121 (0.0560)	0.363 (0.317)	0.0470 (0.0527)	0.0187 (0.0426)	-0.0971* (0.0514)	-0.0622 (0.0408)
Year 2	-0.00826 (0.0632)	0.0321 (0.277)	0.0440 (0.0469)	-0.0351 (0.0388)	0.0497 (0.0538)	0.0572 (0.0464)
Observations	4,397	4,397	4,397	4,397	4,394	4,397
R-squared	0.047	0.112	0.125	0.376	0.183	0.111

Short-term outcomes

	(1) Respiratory problem (wave 2)	(2)	(3) Height for age (z-score)	(4)	(5) Stunted	(6)
In-utero	-0.0368 (0.236)	-0.0357 (0.242)	-0.405* (0.225)	-0.399* (0.222)	0.0334 (0.0660)	0.0318 (0.0676)
Year 1	0.165* (0.0939)	0.177* (0.0935)	-0.169 (0.143)	-0.180 (0.142)	0.0356 (0.0551)	0.0402 (0.0546)
Year 2	0.192 (0.117)	0.202* (0.118)	-0.171 (0.159)	-0.155 (0.156)	0.0691 (0.0594)	0.0681 (0.0584)
Obs.	1,340	1,340	3,142	3,142	3,142	3,142
R-sq.	0.161	0.166	0.201	0.214	0.154	0.163
HH char.	N	Y	N	Y	N	Y

Medium-term outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
	Height (in cm)		Test score (age-adjusted)		Lung capacity (in log)	
In-utero	-3.000*** (0.828)	-3.042*** (0.844)	0.0330 (0.135)	0.0422 (0.135)	-0.0584* (0.0325)	-0.0582* (0.0331)
Year 1	-0.625 (0.985)	-0.501 (0.990)	-0.0514 (0.137)	-0.0523 (0.141)	-0.0566** (0.0244)	-0.0518** (0.0250)
Year 2	-0.279 (1.047)	-0.102 (1.026)	0.156 (0.130)	0.176 (0.133)	-0.0768*** (0.0292)	-0.0754** (0.0295)
Obs.	3,883	3,883	3,119	3,119	2,434	2,434
R-sq.	0.670	0.675	0.138	0.160	0.370	0.375
HH char.	N	Y	N	Y	N	Y

Heterogeneity

- Differential effects by:
- Gender
- Poverty
- Urban

Heterogeneity: Gender

	(1) Height for age	(2) Stunted	(3) Height	(4) Test score	(5) Lung capacity
Male	-0.114** (0.0566)	0.0401** (0.0166)	-0.720*** (0.243)	-0.0139 (0.0378)	0.0917*** (0.0111)
In-utero	-0.579** (0.284)	0.0889 (0.0896)	-3.698*** (1.357)	-0.0865 (0.181)	-0.0599 (0.0484)
Year 1	-0.180 (0.176)	0.106 (0.0689)	-0.0277 (1.367)	0.159 (0.163)	-0.00749 (0.0306)
Year 2	-0.327 (0.203)	0.113 (0.0875)	1.774 (1.295)	0.114 (0.167)	-0.0778** (0.0395)
Male x in-utero	0.305 (0.276)	-0.0846 (0.103)	1.081 (1.634)	0.246 (0.206)	0.00489 (0.0601)
Male x Year 1	0.00983 (0.240)	-0.148 (0.0930)	-0.850 (1.669)	-0.388** (0.194)	-0.0832** (0.0338)
Male x Year 2	0.315 (0.249)	-0.0948 (0.0998)	-3.284** (1.629)	0.117 (0.174)	0.00469 (0.0481)
Observations	3,142	3,237	3,883	3,119	2,434
R-squared	0.214	0.166	0.676	0.161	0.376

Heterogeneity: Poor

	(1) Height for age Stunted	(2) Height	(3) Height	(4) Test score	(5) Lung capacity
Poor	-0.135** (0.0671)	0.0368* (0.0206)	-0.894*** (0.294)	-0.202*** (0.0445)	-0.0422*** (0.0133)
In-utero	-0.350 (0.228)	0.0669 (0.0774)	-3.440*** (1.177)	-0.0216 (0.179)	-0.0820** (0.0406)
Year 1	-0.216 (0.185)	0.0502 (0.0694)	-0.355 (1.393)	0.0314 (0.148)	-0.0594* (0.0319)
Year 2	-0.180 (0.173)	0.0257 (0.0733)	0.190 (1.183)	0.164 (0.146)	-0.0951** (0.0370)
Poor x in-utero	-0.134 (0.430)	-0.100 (0.142)	1.095 (1.569)	0.155 (0.275)	0.0629 (0.0687)
Poor x Year 1	0.0750 (0.275)	-0.0281 (0.102)	-0.276 (1.677)	-0.159 (0.205)	0.00753 (0.0428)
Poor x Year 2	0.0579 (0.243)	0.0873 (0.106)	-0.623 (1.970)	0.0220 (0.169)	0.0395 (0.0439)
Observations	3,142	3,237	3,883	3,119	2,434
R-squared	0.214	0.166	0.675	0.161	0.375

Heterogeneity: Urban

	(1) Height for age	(2) Stunted	(3) Height	(4) Test score	(5) Lung capacity
Urban	0.293*** (0.0922)	-0.0554** (0.0264)	1.301*** (0.389)	0.0303 (0.0653)	0.0251 (0.0172)
In-utero	-0.459* (0.258)	0.00564 (0.0782)	-2.284** (0.897)	-0.00746 (0.163)	-0.0397 (0.0388)
Year 1	-0.163 (0.161)	0.0354 (0.0617)	-0.661 (1.136)	-0.180 (0.164)	-0.0618** (0.0287)
Year 2	-0.109 (0.174)	0.0428 (0.0685)	-0.229 (1.245)	0.215 (0.166)	-0.0651** (0.0316)
Urban x in-utero	0.220 (0.431)	0.113 (0.144)	-3.099 (2.061)	0.165 (0.248)	-0.0851 (0.0586)
Urban x Year 1	-0.0365 (0.272)	-0.00137 (0.112)	0.673 (1.954)	0.476** (0.228)	0.0405 (0.0498)
Urban x Year 2	-0.152 (0.252)	0.0787 (0.107)	0.433 (1.790)	-0.111 (0.237)	-0.0422 (0.0572)
Observations	3,142	3,237	3,883	3,119	2,434
R-squared	0.215	0.165	0.675	0.161	0.376

Summary of preliminary results

- Exposure to pollution associated with persistent effects
- Boys more affected
- Selective mortality by gender a potential concern, although earlier work does not find significant gender effects (Jayachandran 2009)
- No heterogeneity by poverty
- Urban doesn't seem to be protective

Hypothesized channels

- Maternal health: blood pressure, difficulty breathing, and lung capacity:
- Pregnant women were affected by the fires, therefore children in-utero were affected
- Breast-feeding:
- If mothers were less healthy, breast milk production may be affected, and breast feeding rates would decline
- Birth spacing:
- If mothers were less healthy (and children were sick), birth spacing may increase

Channels

	(1) Breast feeding	(2) Birth spacing	(3) Lung capacity	(4) Blood pressure	(5) BMI
In-utero	0.0317 (0.0437)	1.936 (5.434)	-8.454 (13.28)	-2.270 (4.722)	-0.233 (0.351)
Year 1	0.0223 (0.0603)	4.641 (6.858)			
Year 2	0.0595 (0.0621)	6.071 (7.590)			
Obs.	2,704	2,458	1,195	1,206	1,195
R-sq.	0.413	0.154	0.362	0.201	0.131

Robustness: 1.25 threshold

	(1) Respiratory problem (wave 2)	(2)	(3) Height for age (z-score)	(4)	(5) Stunted	(6)
In-utero	-0.133 (0.209)	-0.131 (0.208)	-0.319 (0.200)	-0.328* (0.197)	-0.0168 (0.0606)	-0.0137 (0.0618)
Year 1	0.132 (0.0932)	0.144 (0.0934)	-0.211 (0.133)	-0.243* (0.134)	0.0353 (0.0492)	0.0456 (0.0490)
Year 2	0.175 (0.109)	0.190* (0.110)	-0.167 (0.148)	-0.153 (0.144)	0.0613 (0.0549)	0.0590 (0.0542)
Obs.	1,338	1,338	3,139	3,139	3,234	3,234
R-sq.	0.161	0.166	0.201	0.213	0.156	0.165
HH char.	N	Y	N	Y	N	Y

Robustness: 1.25 threshold

	(1)	(2)	(3)	(4)	(5)	(6)
	Height (in cm)		Test score (age-adjusted)		Lung capacity (in log)	
In-utero	-2.310*** (0.782)	-2.414*** (0.791)	-0.0316 (0.131)	-0.0233 (0.130)	-0.0677** (0.0309)	-0.0691** (0.0311)
Year 1	-0.336 (0.933)	-0.324 (0.936)	-0.0405 (0.127)	-0.0550 (0.129)	-0.0576** (0.0234)	-0.0563** (0.0239)
Year 2	-0.0449 (0.896)	0.0972 (0.875)	0.144 (0.112)	0.164 (0.114)	-0.0729*** (0.0264)	-0.0717*** (0.0267)
Obs.	3,882	3,882	3,117	3,117	2,433	2,433
R-sq.	0.670	0.675	0.139	0.161	0.371	0.376
HH char.	N	Y	N	Y	N	Y

Next steps

- Other parental investments that mitigate cognitive effects (compensating vs reinforcing):
- Health and education expenditure, parental employment
- Placebo/falsification tests