Early life exposure to air pollution, cognitive development, and labor market outcomes

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The economic costs of air pollution are high

- Estimates of costs include health cost, imputed cost due to morbidity and mortality, lost economic activity
  - Cost estimates are used as inputs into cost-benefit analysis
- If not all costs are accounted for, there may be underinvestment in prevention and mitigation
- Costs associated with early life exposure has received limited attention

Early life shocks have long-term consequences

- Literature shows large impacts of early life shocks (famine, drought, earthquake, etc) on a wide range of adult health, education, labor supply, and earnings
- Exposure in-utero is especially consequential
- Exposure to air pollution early in life may also have negative consequences later in life
- Negative effect on cognitive development would lead to lost labor market earnings

Research question

What was the economic cost of early-life exposure to air pollution caused by forest fires in Indonesia in 1997?

- Two-step approach
  1. Estimate the effect of exposure on cognitive ability
  2. Estimate the effect of cognitive ability on earnings

Key results

- Early life exposure to air pollution caused by 1997/98 Indonesian fires reduced the scores in tests of cognitive ability ten years later
- The impact is higher on those born in poorer households
- The estimated economic cost could be equivalent to 2.5-5% of labor market earnings

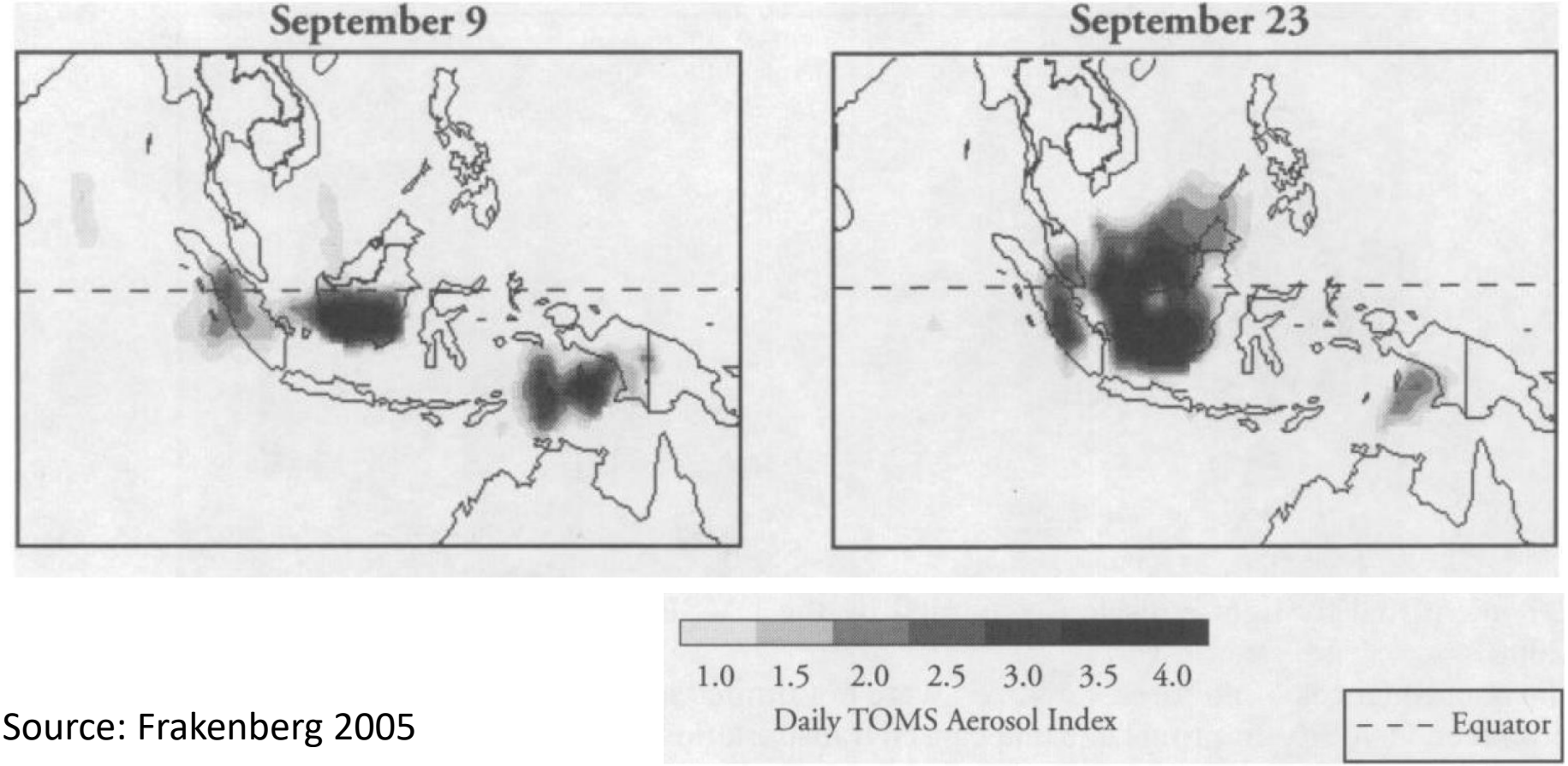
The 1997 Indonesian forest fires

- Large tracts of forests burnt: 4.5-6 million hectares (2-3% of Indonesian land area)
- Multiple contributory factors: Dry year; Burning practices
- Consequences include destruction of tropical forests and farmland, habitat loss, release of greenhouse gases into the atmosphere, and health hazards

Air pollution due to forest fires in Indonesia

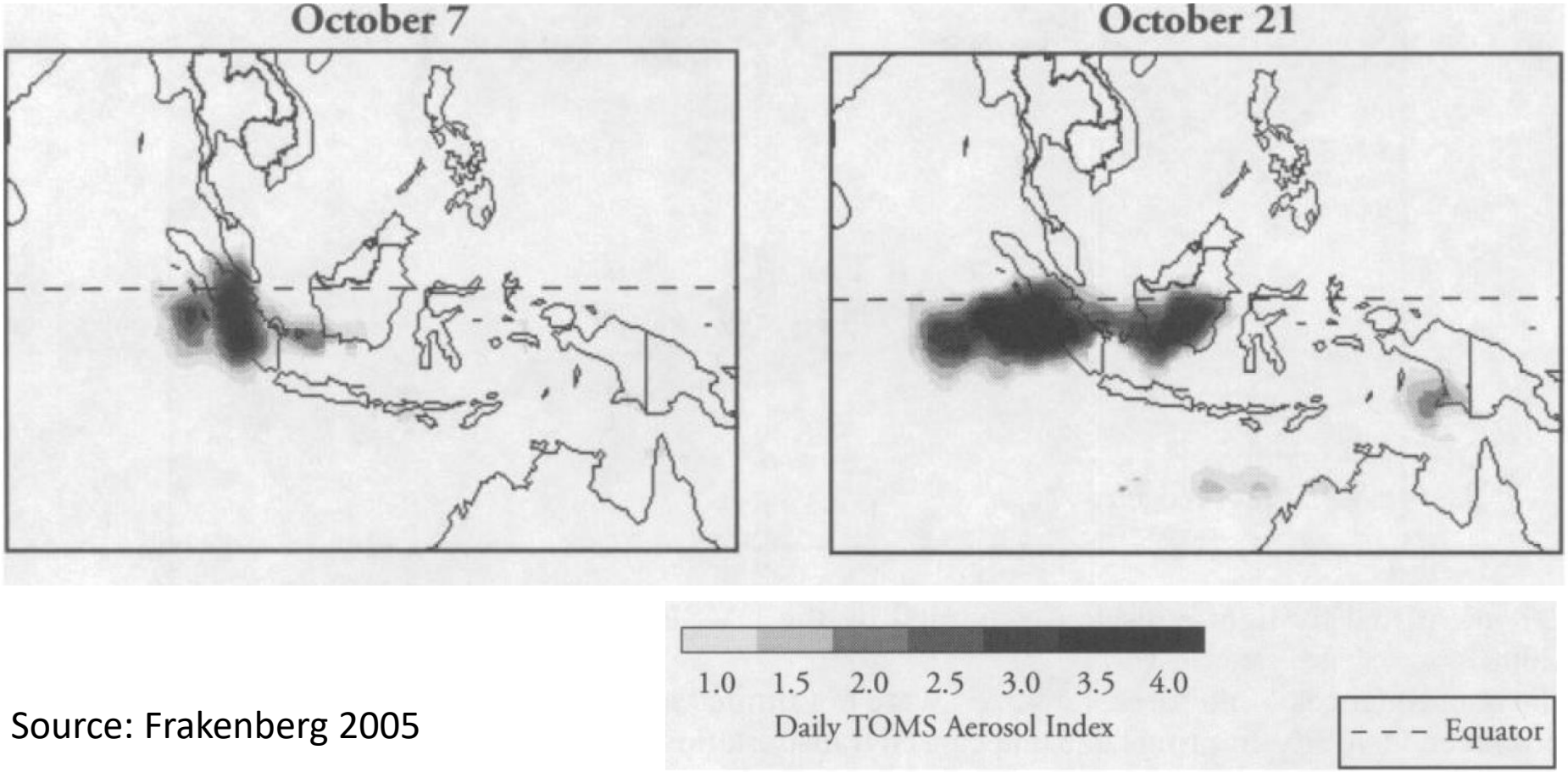
- Resultant smog and haze affected large parts of Indonesia and neighboring countries
  - ~70 million people affected
  - In Indonesia, exposure limited to Sumatra and Kalimantan
  - Very strong spike in pollution: “like smoking 80 cigarettes a day”

Satellite-based pollution level: Sept 1997



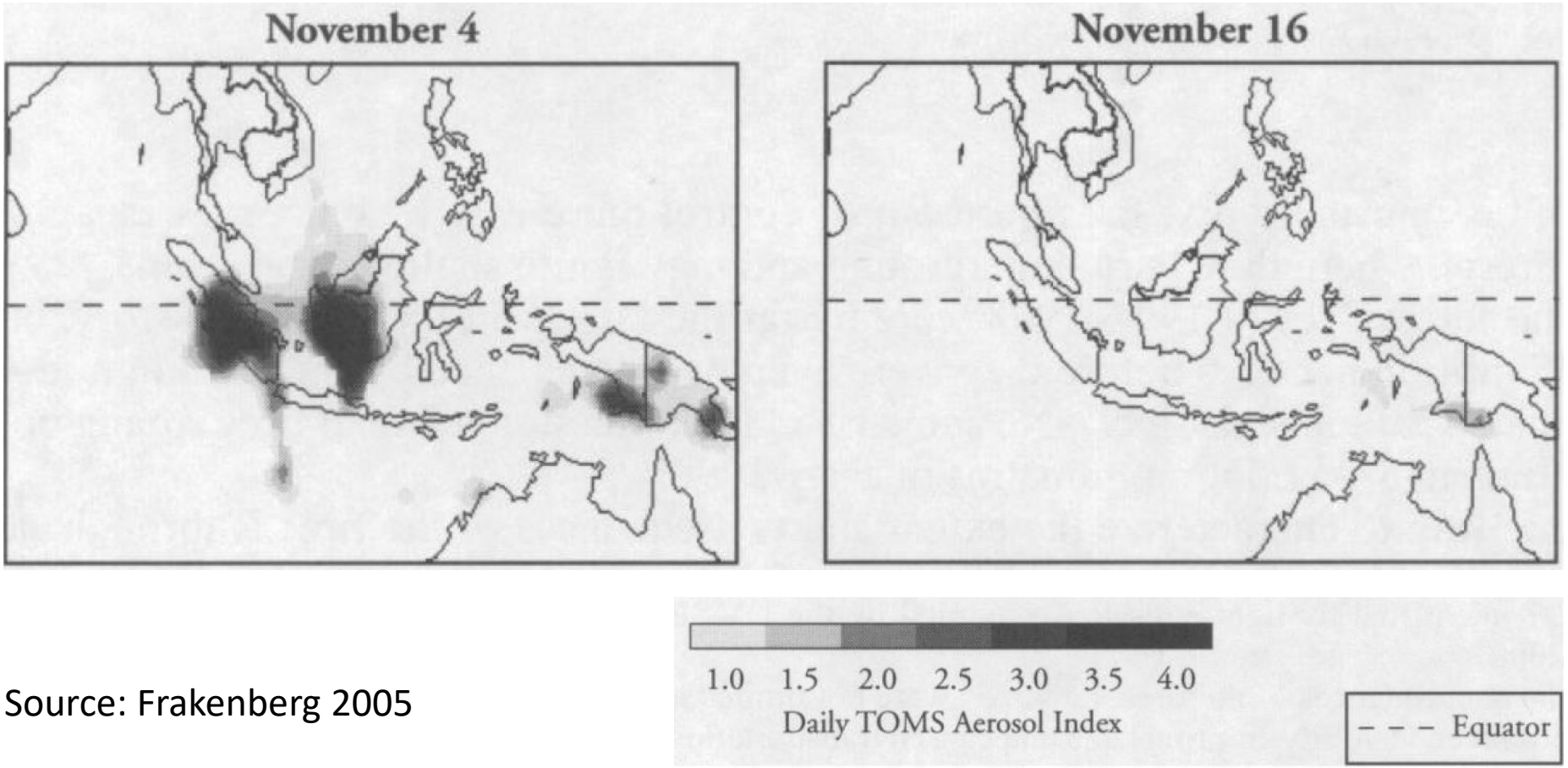
Source: Frakenberg 2005

Satellite-based pollution level: Oct 1997



Source: Frakenberg 2005

Satellite-based pollution level: Nov 1997



Source: Frakenberg 2005

Pollution and cognitive development

- The effect of a transitory pollution shock on adult health is temporary
- In fetuses, pollution may affect brain development and therefore cause more long-term harm
- Compensatory investments may be lacking because negative effects are not obvious
- In poor areas, loss of income and lack of coping mechanism may exacerbate the negative effect

Related literature is growing

- The literature assessing long-term impact of exposure to air pollution is small but emerging
  - Voorheis (2017); Isen et al (2016) – impact of air pollution reduction due to the 1970 Clean Air act in the US
  - Bharadwaj et al. (2017) in Chile – strong negative effect from fetal exposure to carbon monoxide on math and language skills measured in 4th grade
  - Chen et al. (2017) in China - contemporaneous and cumulative exposure to air pollution impedes both verbal and math scores

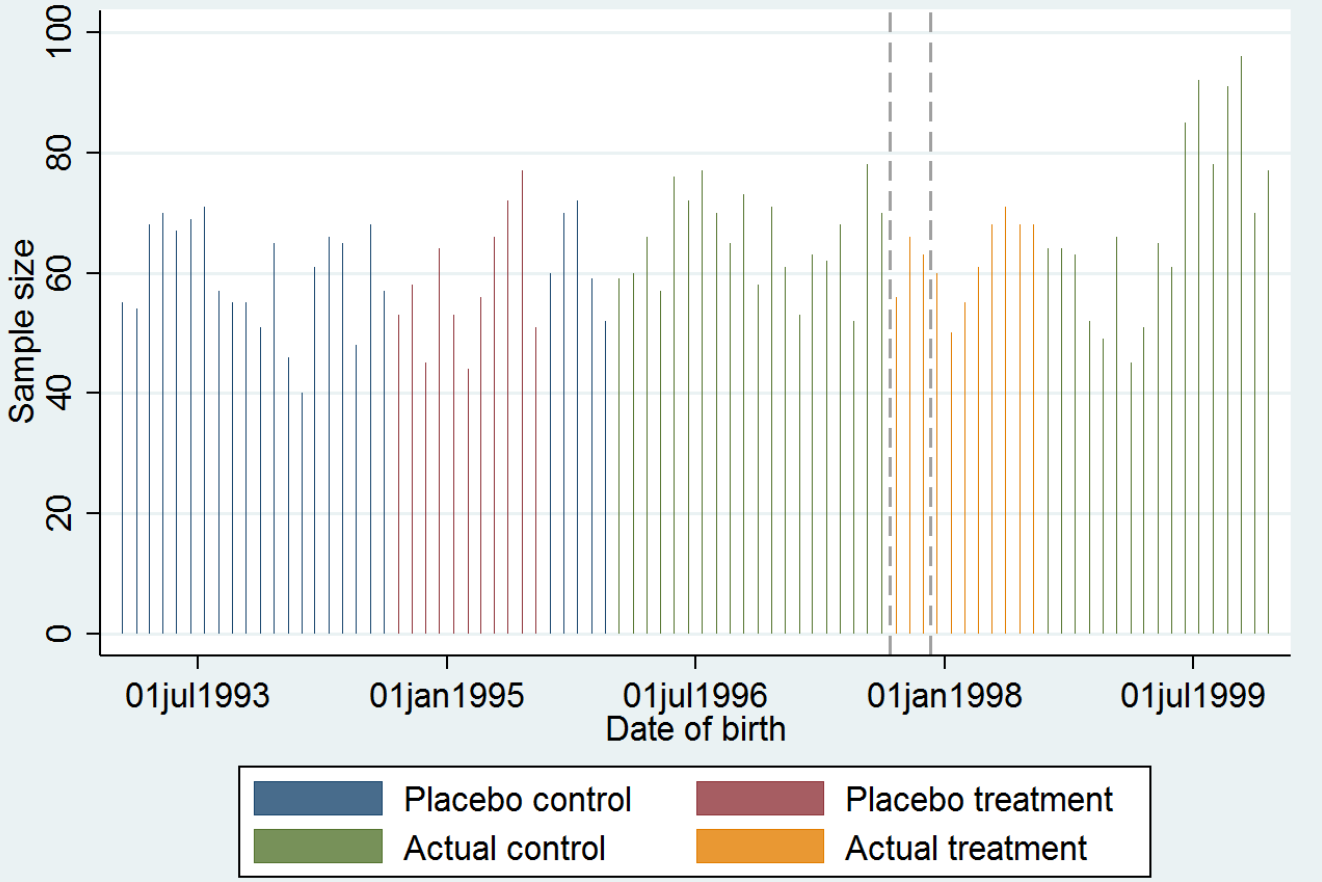
Studies find large impacts of the Indonesian fire

- Frakenberg et al. (2005) – immediate health
  - Between 1993 and 1997, individuals exposed to haze experienced greater increases in difficulty with daily activities
- Jayachandran (2009) – infant and child mortality
  - the pollution led to 15,600 missing children Indonesia (1.2% of the affected birth cohort)
- Kim et al. (2017) – long term health
  - an extra standard deviation in the pollution level increases the likelihood of a poor general health status by almost 3%.
- This paper – cognitive development and potential labor market outcomes

Econometric approach

- Diff-in-diffs analysis using Indonesian Family Life Survey
- Month and region of birth determine exposure to pollution (extensive margin)
  - Those born between Sep 1997 and July 1998 in West Sumatera, Riau, Jambi, Central Kalimantan, East Kalimantan, West Kalimantan were exposed to the pollution
  - Control group are individuals born between Jan 1996 – Aug 1997 and Aug 1998 – Dec 1999
  - Robustness check using a sample comprising of entirely unaffected cohort

Study design: estimation sample



Dashed line bookends the period of 1997 forest fire

Provincial variation in exposure

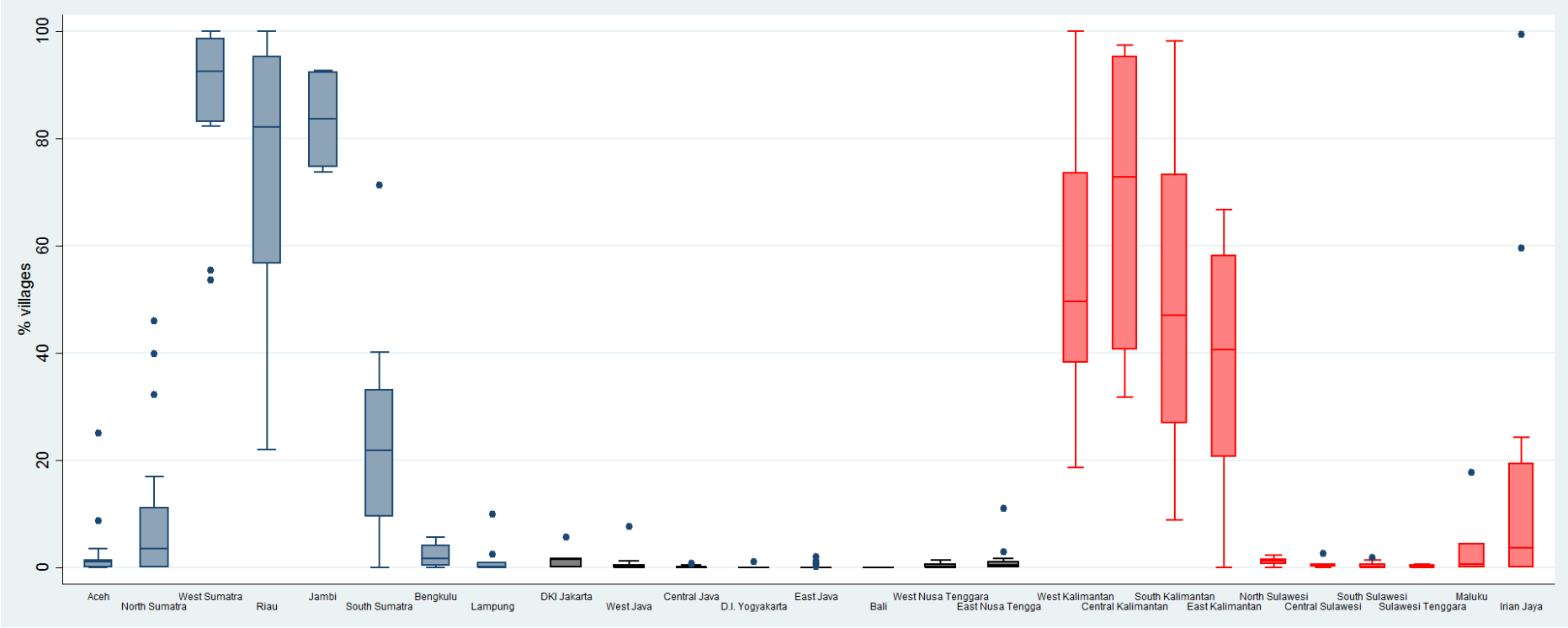


Figure: % of villages in a sub-district reporting air pollution over the past three years

Source: PODES 2000

Outcome: cognitive ability

- Cognitive ability an important factor in labor market earnings
- In IFLS, it is measured by administering an standardized Raven's pattern recognition test and mathematics questions

Summary of 2007 sample

	Mean	SD
Total score	11.49	3.14
Cognitive score	8.66	2.45
Mathematics score	2.91	1.19
Age of respondent	9.65	1.23
Male	0.51	0.50
Household's per capita consumption in 2000	11.90	0.69
Exposed region	0.10	0.30
Exposed cohort	0.22	0.41
Observations	2843	

Impact of pollution exposure actual sample

	(1) Baseline	(2) Controls	(3) Poorer	(4) No Java
Exposed cohort	0.0630	0.105	0.112	0.221
	(0.176)	(0.175)	(0.252)	(0.280)
Exposed region	1.152***	1.142***	1.490***	1.187***
	(0.364)	(0.358)	(0.535)	(0.362)
Exposed cohort X	-0.859**	-0.876**	-1.606***	-1.041**
region	(0.391)	(0.382)	(0.565)	(0.429)
Female	0.0275	0.0371	0.0133	-0.172
	(0.112)	(0.111)	(0.160)	(0.171)
_cons	11.23***	2.481**	2.873	3.095*
	(0.251)	(1.033)	(2.597)	(1.684)
Add controls	No	Yes	Yes	Yes
Observations	2843	2835	1498	1235
R^2	0.102	0.127	0.091	0.127

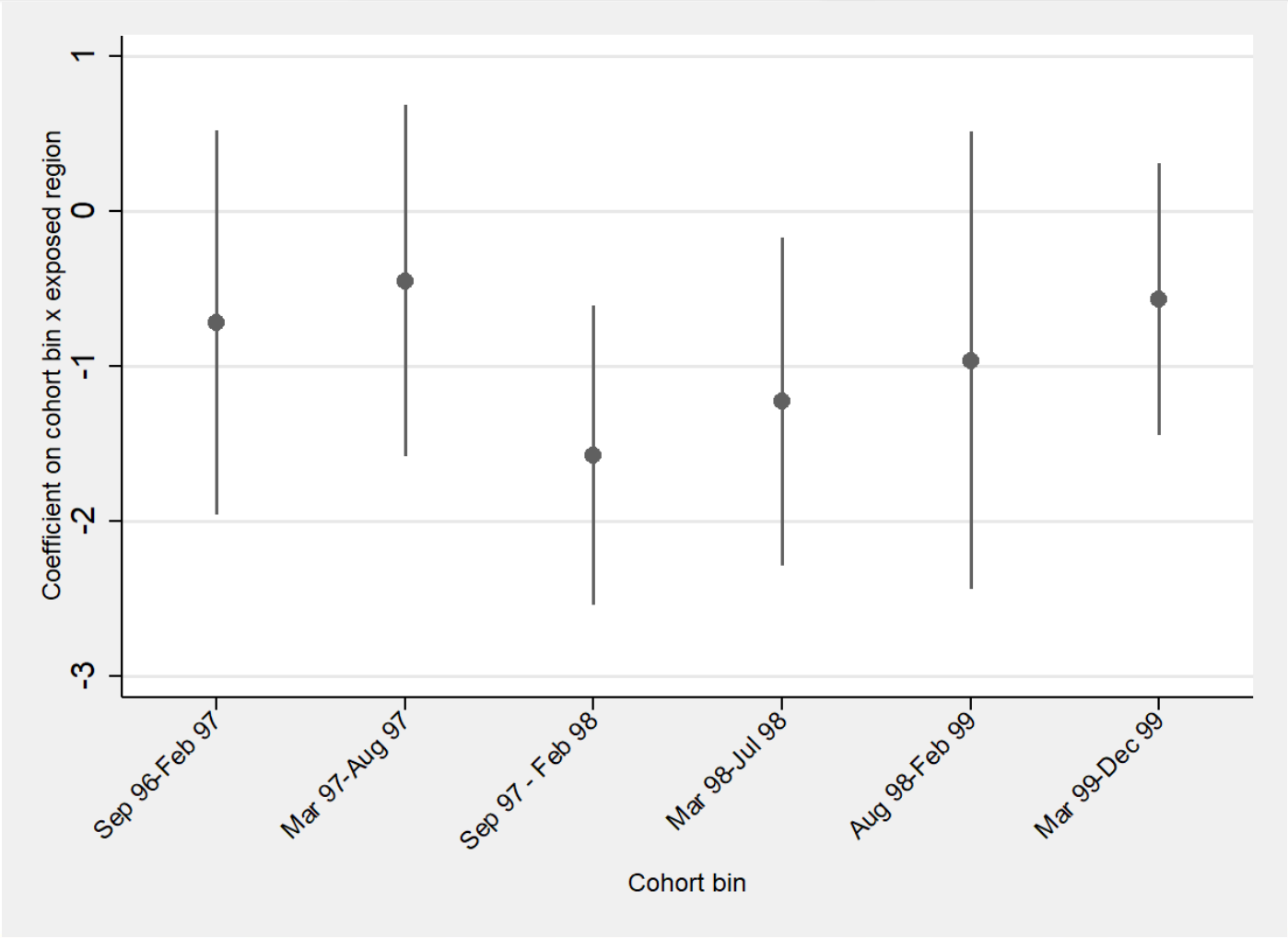
Robustness check with placebo sample

	(1) Baseline	(2) Controls	(3) Poorer	(4) No Java
Exposed cohort	-0.257	-0.212	-0.409*	-0.195
	(0.158)	(0.155)	(0.222)	(0.268)
Exposed region	0.994***	0.983***	1.092**	0.972***
	(0.302)	(0.300)	(0.455)	(0.306)
Exposed cohort X	0.242	0.203	0.0491	0.197
region	(0.383)	(0.380)	(0.597)	(0.428)
Female	0.107	0.125	0.262*	0.148
	(0.104)	(0.102)	(0.146)	(0.161)
_cons	12.09***	4.282***	5.117**	4.725***
	(0.226)	(0.971)	(2.334)	(1.477)
Add controls	No	Yes	Yes	Yes
Observations	2767	2759	1458	1238
R^2	0.089	0.113	0.122	0.131

The impact of Asian Financial Crisis?

- AFC characterized by rapid depreciation of Indonesian Rupiah, negative GDP growth
- Main consequences of AFC include increase in food prices, reduced health behavior (Frankenberg et al. 1999)
- But, AFC affected households in all parts of Indonesia, not just those provinces affected by air pollution
  - Estimates in the paper are an additional effect on top of any negative consequences of AFC

Coefficients by cohort bins



Relation between cognitive score & earnings

	(1)	(2)	(3)	(4)
Total score 2000	0.0578***	0.0359***	0.0497***	0.0329***
	(0.00861)	(0.00886)	(0.00853)	(0.00882)
Education				
Junior		0.144		0.139
		(0.106)		(0.106)
Senior		0.605***		0.570***
		(0.104)		(0.106)
Tertiary		0.690***		0.599***
		(0.113)		(0.117)
Log consumption 1993			0.239***	0.170***
			(0.0423)	(0.0432)
Observations	2279	2279	2279	2279
Number of clusters	170	170	170	170

Economic effect of air pollution

- A one point higher score is associated with 3% higher earnings
- Effect on earnings due to air pollution is between 2.8 – 5.3%
- An underestimate because other channels (e.g. health) may also produce additional effect
- Need more data once the affected cohort enter the labor market

Other results

- Additional controls (mother's education, height) no not substantially change the results (baseline coeff is -0.67, p=0.04)
- Disaggregating the dependent variable into Raven's test and mathematics test
  - Effect driven by scores on Raven's test
- No effect found when using the 2014 IFLS. Reasons?
  - Smaller test (8 pattern matching questions rather than 12)
  - Selected sample

Conclusion

- Air pollution resulting from the 1997/98 haze negatively affected cognitive development of those in utero at the time of the fire
- Households that were poorer at the time show greater impact
- There is long-term cost of air pollution that needs to be considered in the cost-benefit analysis
- Further work to ensure that results not contaminated by the AFC

Thank you!

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Impact on 2014 sample

	Baseline	Controls	Poorer	No Java
Exposed cohort	-0.0725	-0.0626	-0.259	-0.227
	(0.167)	(0.153)	(0.192)	(0.216)
Exposed region	0.653**	0.800**	1.255***	0.771**
	(0.331)	(0.311)	(0.435)	(0.317)
Exposed cohort X	0.257	0.343	0.300	0.483
region	(0.369)	(0.363)	(0.495)	(0.386)
Female	0.248**	0.191*	0.181	0.121
	(0.105)	(0.0997)	(0.145)	(0.152)
Educ Junior		1.548***	1.473***	1.288***
		(0.265)	(0.323)	(0.409)
Educ Senior		2.611***	2.254***	2.417***
		(0.243)	(0.299)	(0.372)
Educ college		3.398***	2.767***	3.136***
		(0.342)	(0.512)	(0.529)
_cons	7.908***	1.476	2.718	3.828**
	(0.191)	(0.925)	(2.087)	(1.492)
Add controls	No	Yes	Yes	Yes
Observations	2378	2356	1243	1053
R^2	0.065	0.164	0.148	0.159