Air Quality and Early-Life Mortality: Evidence from Indonesia's Wildfires

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- This paper examines effect of air pollution on fetal and infant survival
- Identifies effects exploiting short time window and spatial variation in smoke
- Infers deaths from "missing people" in 2000 Indonesian Census
  - Will consider alternative explanations for the findings

Main findings

- Exposure to pollution has large impact on survival
  - 1.2% decrease in size of affected cohorts
  - 15,600 child, infant and fetal deaths
- Effect is from in utero exposure to pollution
- Effects are much larger in poor areas

Contributions

- Adds to understanding of pollution and health
  - Spike in pollution allows one to identify the timing of exposure matters most
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  - Estimates relevant for developing countries
- Insight into the SES gradient in health
- Indonesian fires exemplify a broader phenomenon:

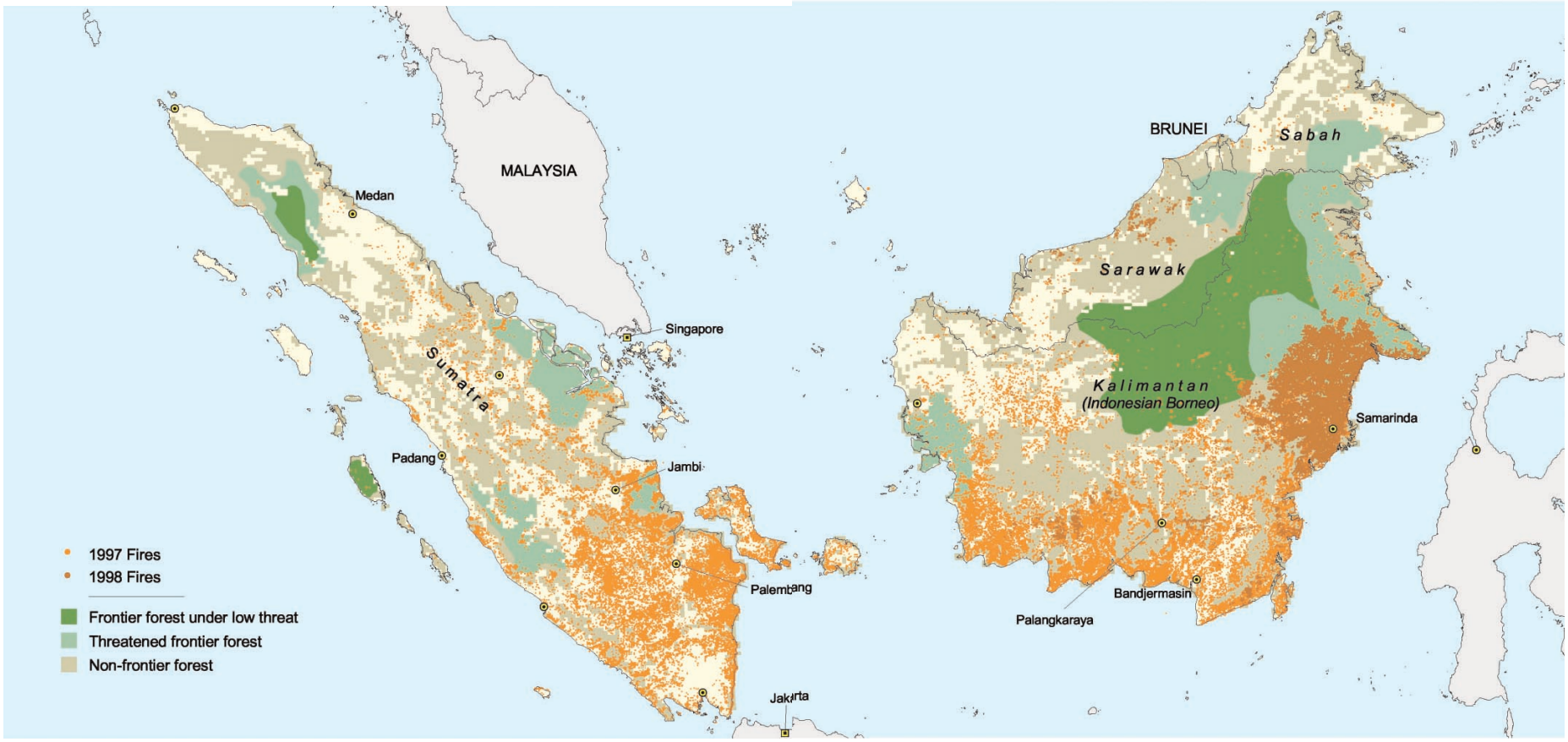
  Environmental degradation enabled by corruption + ineffective regulation

Outline

- Background
  - Indonesian fires
  - Link between air pollution and infant mortality
- Empirical strategy and data
- Results
  - Main results
  - Alternative hypotheses
  - Heterogeneous effects
- Conclusion

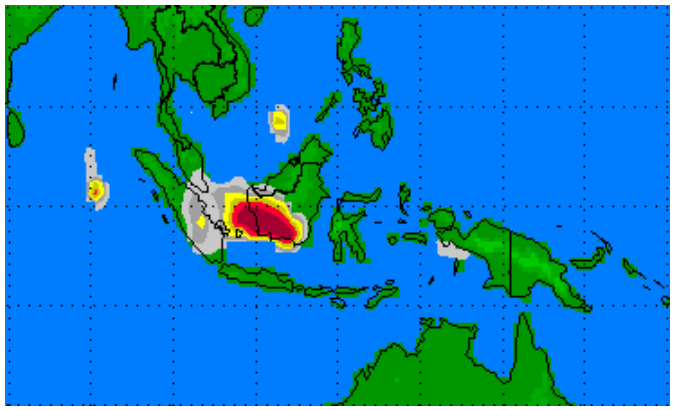
Map of Indonesia

Location of fires

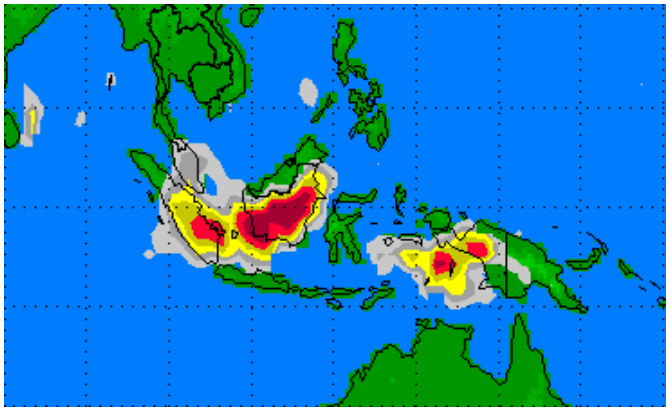


Source: Barber and Schweithhelm (2000)

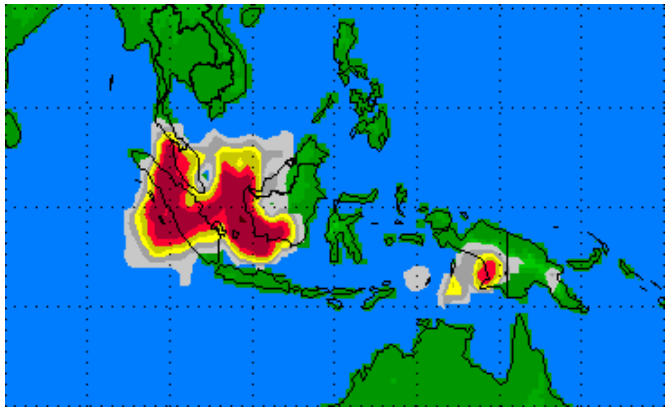
Air pollution over Indonesia during the fires



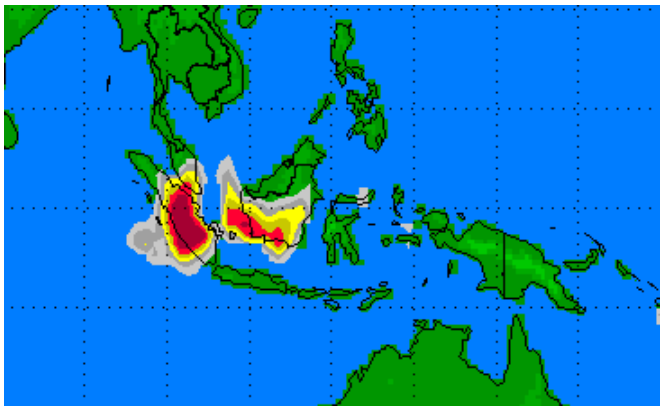
September 5, 1997



September 15, 1997



September 25, 1997



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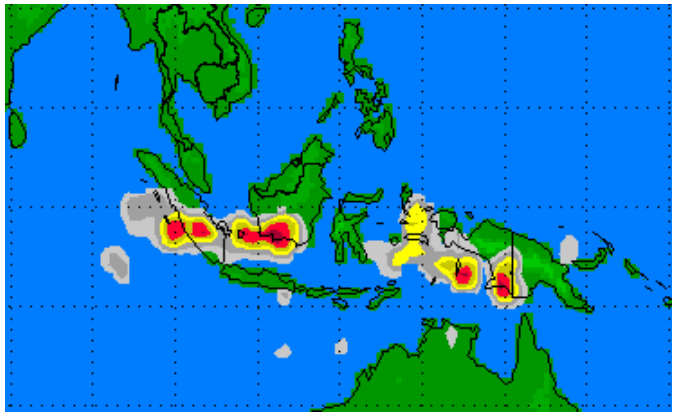

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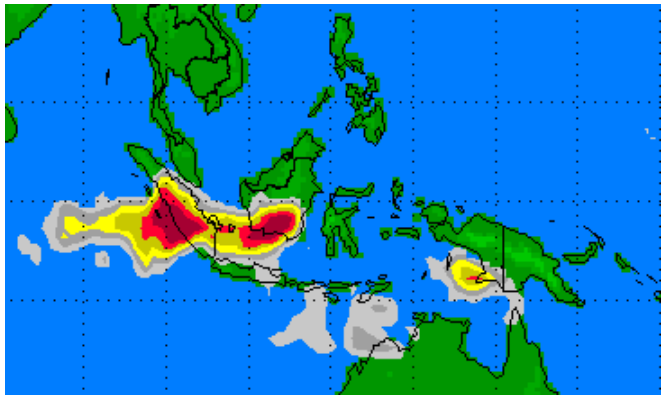

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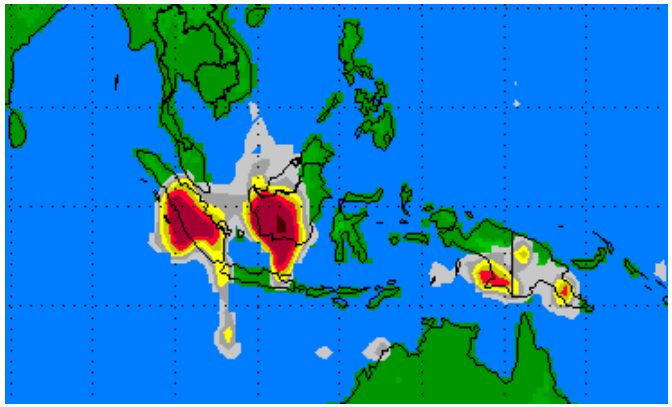
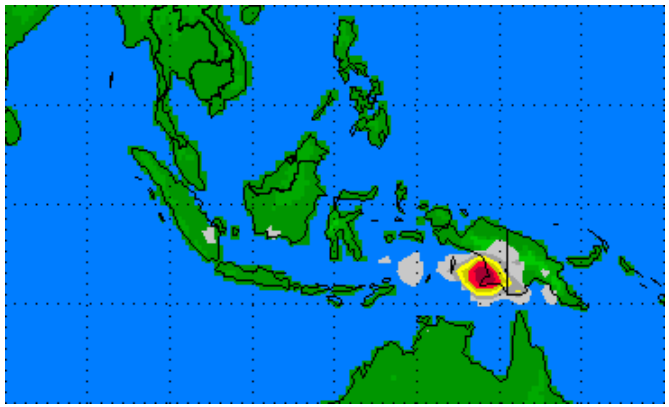


November 4, 1997



November 14, 1997

Causes of the 1997 wildfires

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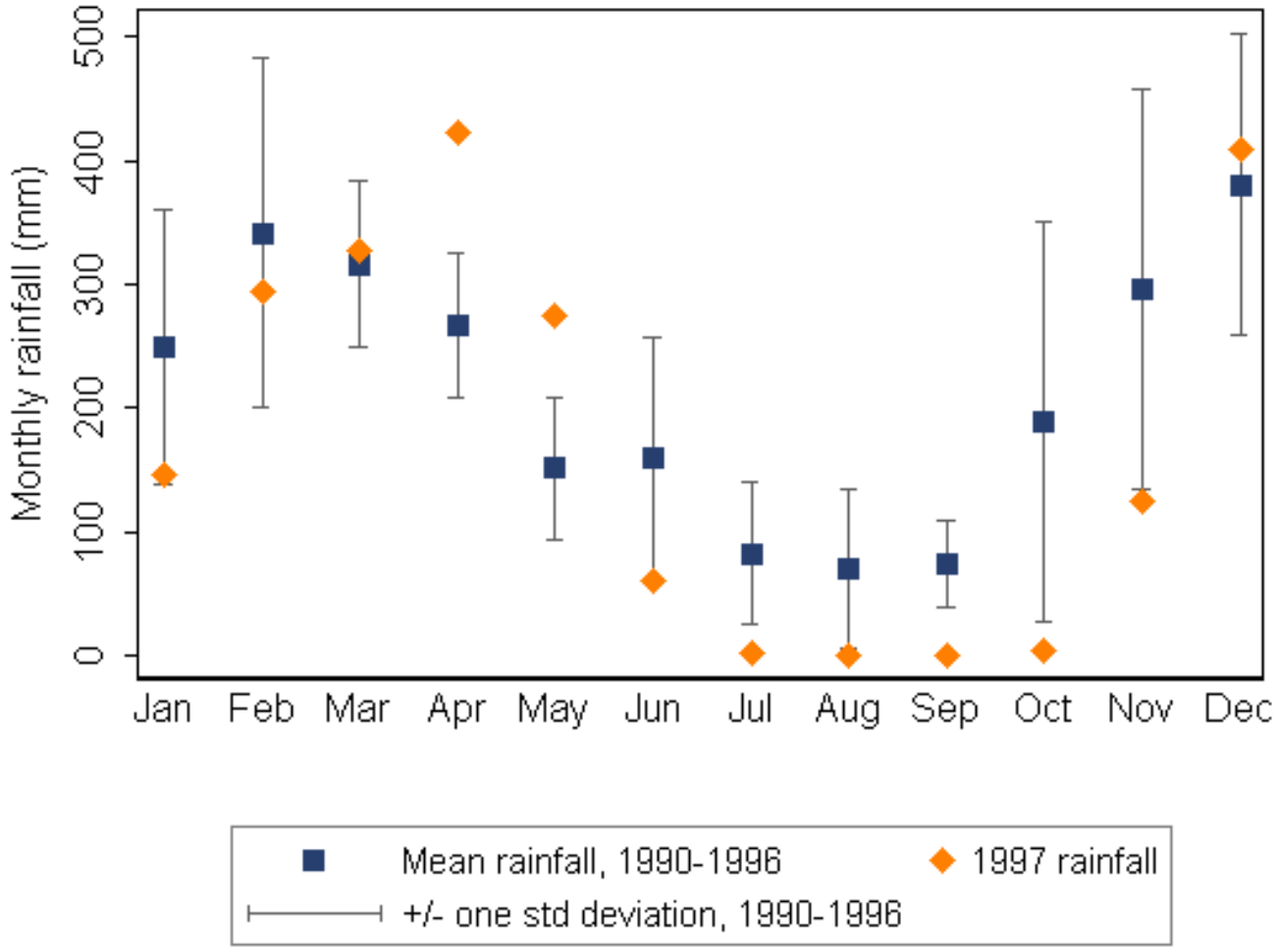
- El Niño

Rainfall in Indonesia in 1997
(Palembang station, South Sumatra)



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- PM_{10} reached over 2000 $\mu\mathrm{g}/\mathrm{m}^3$ and exceeded EPA standard of 150 $\mu\mathrm{g}/\mathrm{m}^3$ on several days in Kalimantan and Sumatra
- Similar to pollution from indoor use of wood-burning stoves

Pollution in Sarawak, Borneo

From the New York Times

"Tigers and elephants are fleeing the burning jungles. Birds are falling from the murky skies. School children are fainting at their desks. Ships are colliding at sea."

From "Its Mood Dark as the Haze, Southeast Asia Aches," NYT, October 26, 1997

Link between air pollution and health

- Possible mechanisms for particulates and health
  - Acute respiratory infection
  - Affects mother's health which in turn fetus' nutrition
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- Sastry (2002), Frankenberg et al (2005) on adult outcomes

Empirical strategy

- Estimating equation is

$$LogCohortSize_{jt} = \beta_1 Smoke_{jt} + \beta_2 PrenatalSmoke_{jt} + \beta_3 PostnatalSmoke_{jt} + \delta_t + \alpha_j + \varepsilon_{jt}$$

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- $CohortSize_{jt}$ is the number of people born in year-month t who are residing in subdistrict j in 2000 (from Census)
  - Fetal, infant and child mortality (through age $\sim$3)
  - Fertility rate, migration, change in gestation period?

Data

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  - Cluster standard errors by month $\times$ island (18 $\times$ 10)

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- Also use SUSENAS (household survey) and PODES (census of villages)

Pollution data

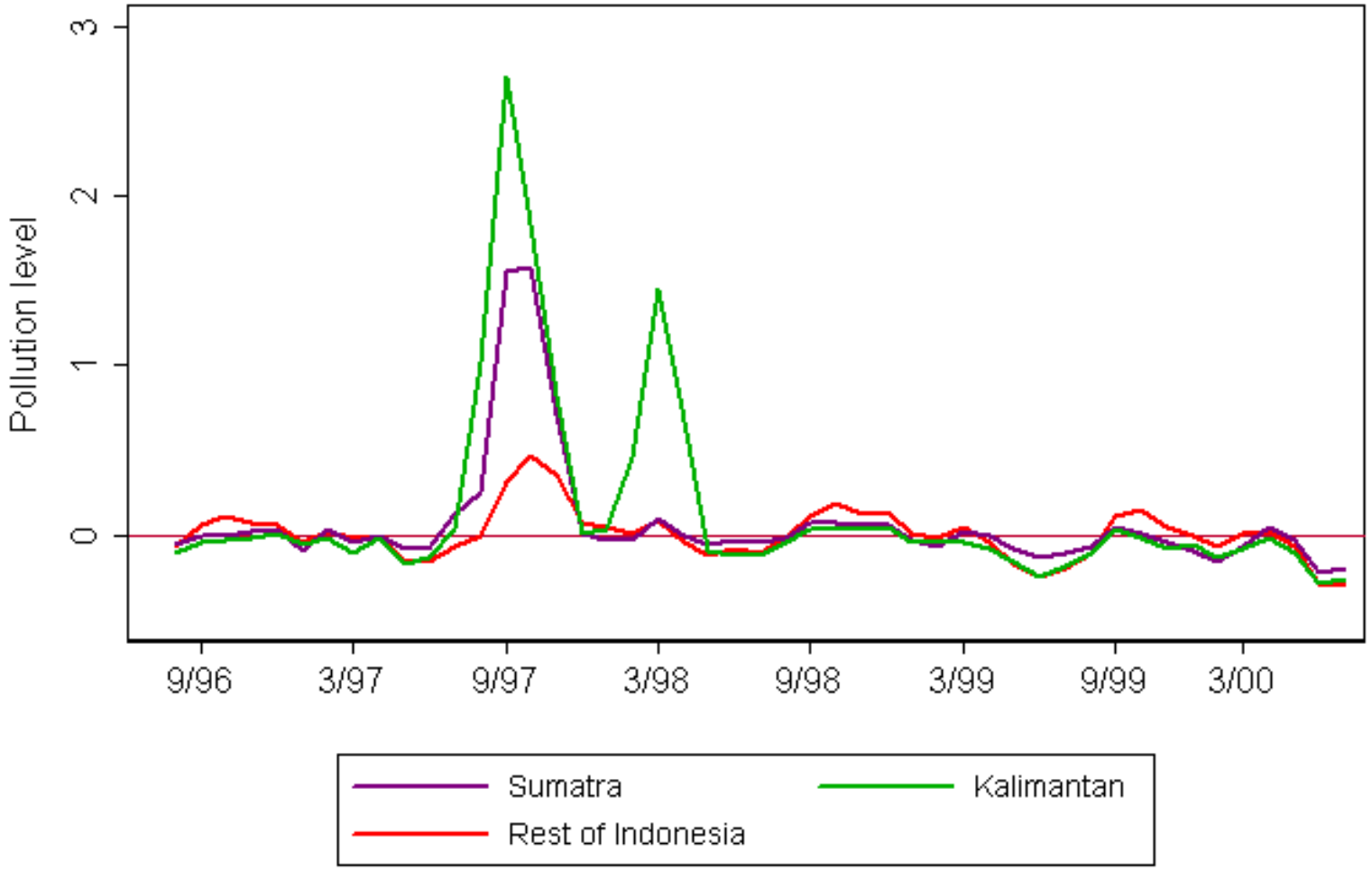

Table 3

Relationship Between Air Pollution and Cohort Size

Dependent variable: Log cohort size

	Statistic used for smoke measures					
	Median	Mean	# of high-smoke days	Median	Mean	# of high-smoke days
	(1)	(4)	(5)	(6)	(7)	(8)
Smoke	-.0005	-.001	-.010	.001	.018	.035
	(.006)	(.007)	(.020)	(.009)	(.014)	(.036)
Prenatal Smoke ($Smoke_{t-1,2,3}$)	-.035 ***	-.032 **	-.085 **			
	(.012)	(.013)	(.033)			
PostnatalSmoke ($Smoke_{t+1,2,3}$)	-.014	-.016 *	-.042 *			
	(.009)	(.010)	(.025)			
$Smoke_{t-1}$				-.010	-.028 *	-.069 *
				(.009)	(.016)	(.040)
$Smoke_{t-2}$				-.023 ***	-.006	-.035
				(.008)	(.013)	(.038)
$Smoke_{t-3}$				-.003	-.005	.005
				(.013)	(.015)	(.030)
$Smoke_{t+1}$				-.010	-.019	-.030
				(.009)	(.014)	(.031)
$Smoke_{t+2}$				-.005	-.003	-.034
				(.008)	(.014)	(.034)
$Smoke_{t+3}$				.001	-.001	.010
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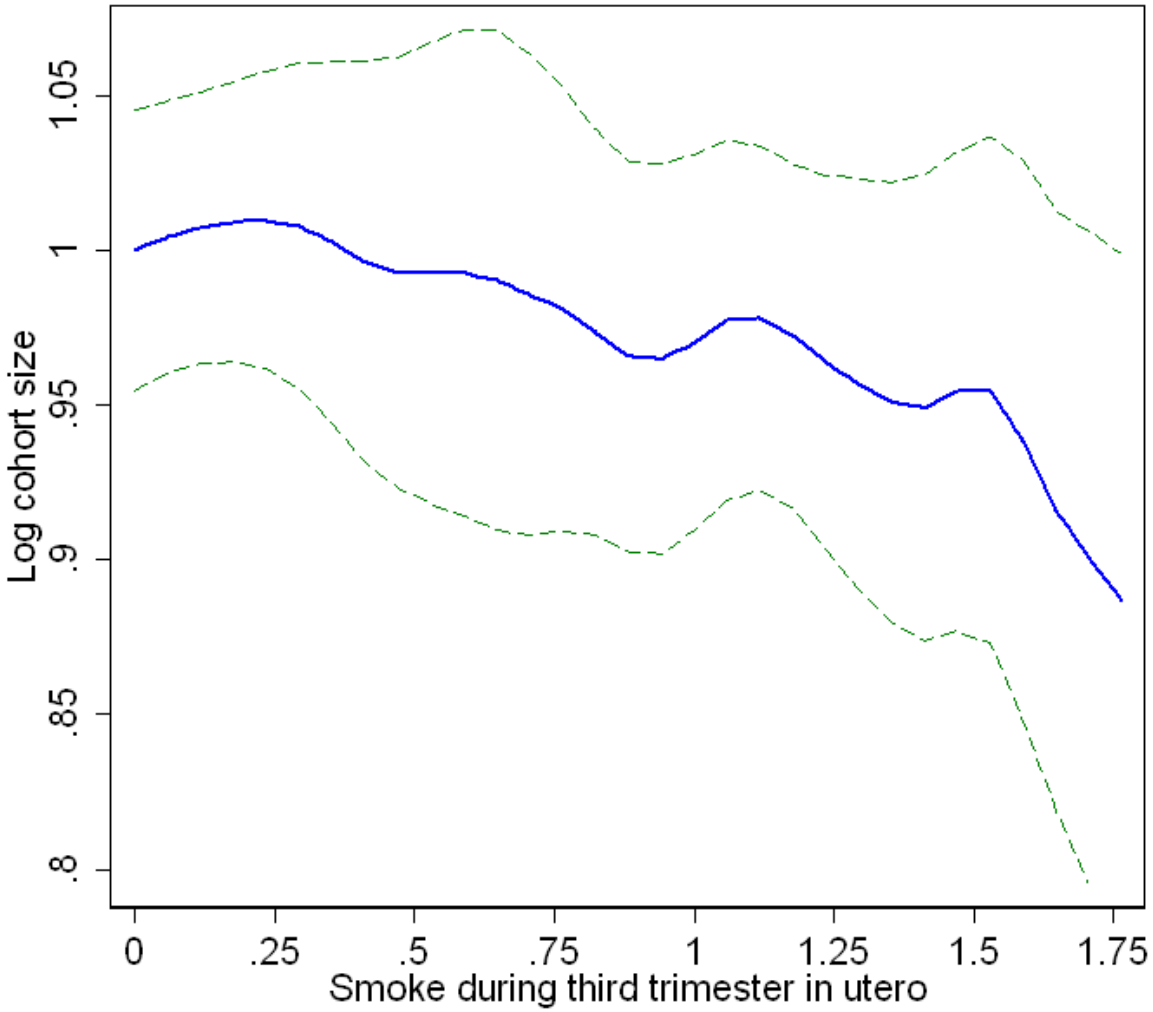
Semiparametric relationship



Alternative hypotheses

- Migration
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- Other hypotheses
  - Change in gestation period
  - Fertility rate
  - Financial crisis
  - Fires per se
  - Drought

Table 4
Distinguishing between Mortality and Migration

Dependent variable: Log cohort size

	By district of residence vs birth vs mother's 1995 residence		
	Residence	Birthplace	Mother's 1995 resid.
	(1)	(2)	(3)
Smoke	-.002	.002	.002
	(.006)	(.006)	(.006)
Prenatal Smoke	-.035 ***	-.037 ***	-.038 ***
	(.012)	(.012)	(.012)
Postnatal Smoke	-.013	-.015	-.016
	(.010)	(.010)	(.010)
Observations	5829	5829	5829

Alternative hypotheses

- Fertility rate as an omitted variable
  - Would have to be an upward or downward spike in specific regions
  - Control for predicted births based on demographics

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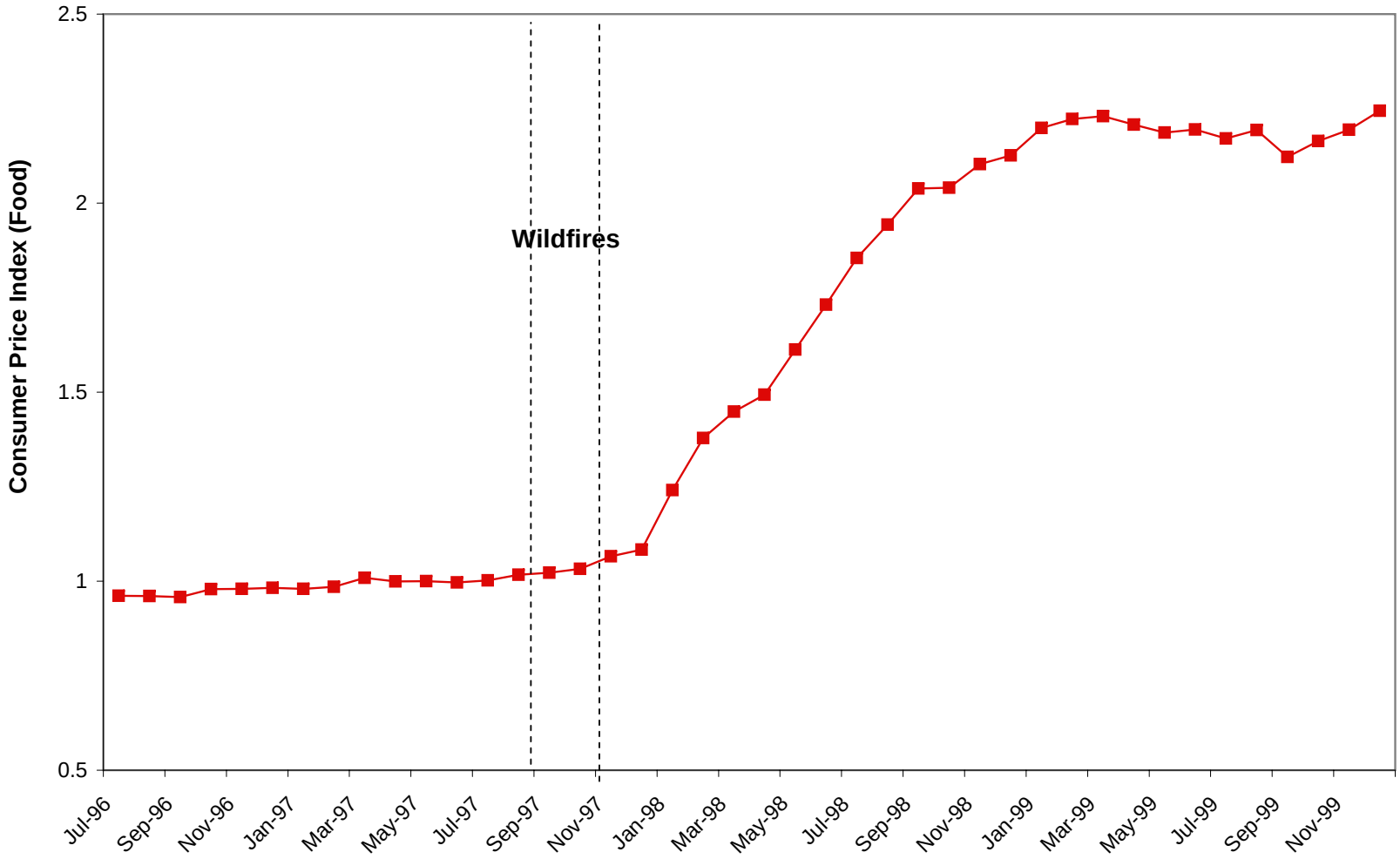
- Fertility rate as an omitted variable
  - Would have to be an upward or downward spike in specific regions
  - Control for predicted births based on demographics
- Change in gestation period
  - Specific concern is that births were induced in August: low value of $PrenatalSmoke$
  - Re-estimate model dropping August
  - NB: Rules out that preterm births occurred $instead\ of$ mortality

Table 5
Alternative Hypotheses: Fertility, Preterm Births

Dependent variable: Log cohort size

	Control for predicted fertility	Excluding August 1997
	(1)	(2)
Smoke	.001	.001
	(.006)	(.006)
Prenatal Smoke	-.035 ***	-.036 ***
	(.012)	(.012)
Postnatal Smoke	-.014	-.009
	(.009)	(.010)
Ln(Predicted Births)	.875	
	(.696)	
Observations	67454	63703

Alternative hypothesis: Financial crisis



Control for financial crisis

- Financial crisis variable
  - Monthly CPI $\times$ ratio of district's median consumption in 1999 to 1996
  - Higher value $\Leftrightarrow$ Harder hit by crisis

Table 5 (continued)
Alternative Hypotheses: Financial Crisis

Dependent variable: Log cohort size	(4)
Smoke	.002
	(.006)
Prenatal Smoke	-.032 ***
	(.011)
Postnatal Smoke	-.012
	(.009)
Financial Crisis	-.049
	(.038)
Observations	63158

Alternative hypotheses

- Fires, not pollution
  - Control for intensity of fires or exclude areas most affected by fires
- Drought, not pollution
  - Control for rainfall relative to normal years

Table 5 (continued)
Alternative Hypotheses: Pollution versus Fires or Drought

Dependent variable: Log cohort size

	Excluding areas with fires	Control for fires	Control for rainfall
	(5)	(6)	(7)
Smoke	.003	.004	0.001
	(.011)	(.006)	0.006
Prenatal Smoke	-.035 **	-.032 **	-0.032 **
	(.018)	(.014)	0.013
Any Fires		-.004	
		(.010)	
Prenatal Any Fires		.007	
		(.017)	
Intense Fires		-.028 *	
		(.016)	
Intense Prenatal Fires		-.017	
		(.025)	
Rainfall			-0.004
			(0.007)
N	52646	67454	67454

Heterogeneity by income

- Different exposure to pollution
  - Behavioral responses: evacuation, strenuous or outdoor activity
  - Housing quality, exposure to other pollution
- Different elasticity
  - Baseline health
  - Medical treatment

Table 6
Effects by Income

Dependent variable: Log cohort size

	By income (log consumption) of the district					
			<---------- one regression ---------->			
			Top quartile	3rd quartile	2nd quartile	Bottom
	(3)	(4)	(5)			
Smoke	-.024	-.010	-.004	-.011	-.028	.002
	(.016)	(.007)	(.009)	(.010)	(.024)	(.045)
Prenatal Smoke	-.129 ***	-.069 ***	-.058 ***	-.076 ***	-.094 **	-.121 **
	(.028)	(.013)	(.018)	(.017)	(.047)	(.061)
Postnatal Smoke	-.047 *	-.032 ***	-.025	-.040 ***	-.046	.009
	(.024)	(.011)	(.016)	(.014)	(.032)	(.052)
Smoke * High Consum.	.017					
	(.014)					
Prenatal Smoke * High Consum.	.072 ***					
	(.027)					
Postnatal Smoke * High Consum.	.017					
	(.014)					
Fixed effects included	subdistrict, month * high cons.	subdistrict, month * high cons.	subdistrict, month*quartile of log consumption			

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Explanations for heterogeneity by income

- Test whether effects vary by
  - Urbanization
  - Indoor use of wood-burning stoves
  - Health care facilities
  - Mother's education
  - (Whether mother works in agriculture)
  - (Distance to pollution-free area)

Table 7

Effects By Urbanization, Wood Fuel Use, and Health Care Sector

Dependent variable: Log cohort size

	(1)	(2)	(3)	(4)	(5)
Prenatal Smoke	-.121 ***	.015	-.115 ***	-.113 ***	-.007
	(.028)	(.032)	(.027)	(.028)	(.025)
Prenatal Smoke * Urbanization	-.013				
	(.013)				
Prenatal Smoke * Wood Fuel Use		-.155 ***			-.120 ***
		(.036)			(.026)
Prenatal Smoke * Matern. Clinic			.030 ***		.011 **
			(.009)		(.005)
Prenatal Smoke * Doctors				.048 ***	.016
				(.015)	(.013)
Prenatal Smoke * High Consum	.071 ***	.048 *	.058 **	.052 **	.044 *
	(.027)	(.025)	(.025)	(.025)	(.025)

Other variables in the regressions: Smoke, Postnatal Smoke and interactions

Table 8: Effects by Mother's Education

Dependent variable: Log cohort size

	Measure of mother's education	
	Individual-specific	Subdistrict average
	(1)	(2)
Smoke	.002	-.004
	(.007)	(.012)
Prenatal Smoke	-.041 ***	-.054 ***
	(.013)	(.018)
Postnatal Smoke	-.010	-.036 **
	(.012)	(.018)
Educated Mother (junior high +)	-.007	
	(.005)	
Smoke * Educated Mother	.007	
	(.008)	
Prenatal Smoke * Educated Mother	-.010	
	(.009)	
Postnatal Smoke * Educated Mother	.098 *	
	(.052)	
Smoke * % Educated Mothers		.003
		(.020)
Prenatal Smoke * % Educated Mothers		.021
		(.029)
Postnatal Smoke * % Educ. Mothers		.057 *
		(.034)
Observations	134908	63158
Fixed effects included	subdistrict * educ. mother, month * educated mother	subdistrict, month * % educ. mothers

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Conclusions

- Fires associated with 1% reduction in surviving infant cohorts, or 15,600 missing children
- Effect is from prenatal exposure
- Much bigger effect on the poor
  - Indoor air pollution, health care, and parental education may be part of explanation
  - Why this health shock had a bigger effect on the poor remains an open question

Environmental issues in developing countries

- Corruption contributes to weak environmental policy
- Health burden of environmental problems might be borne disproportionately by the poor