population density and the effect of sanitation on early-life health

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thank you!

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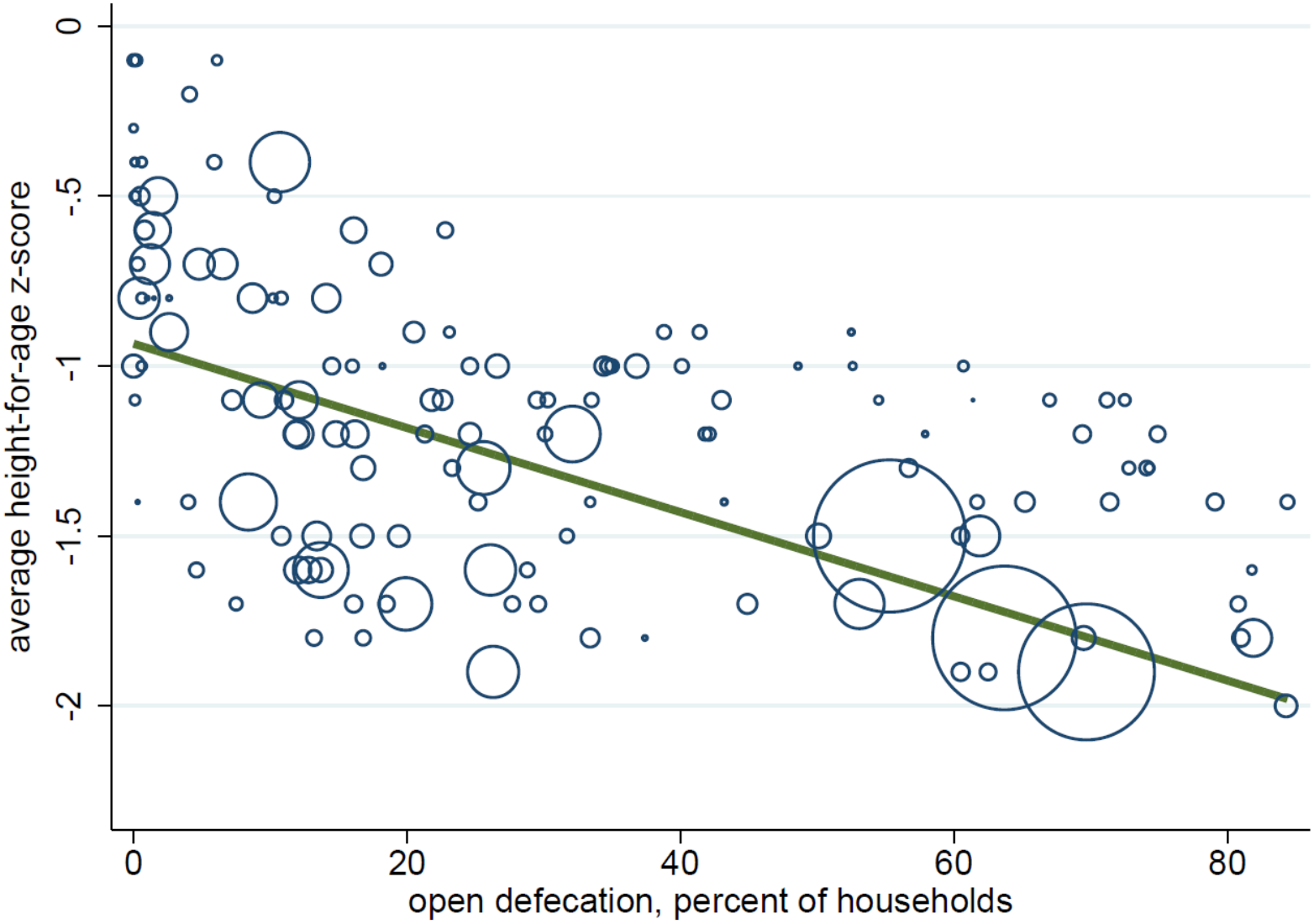
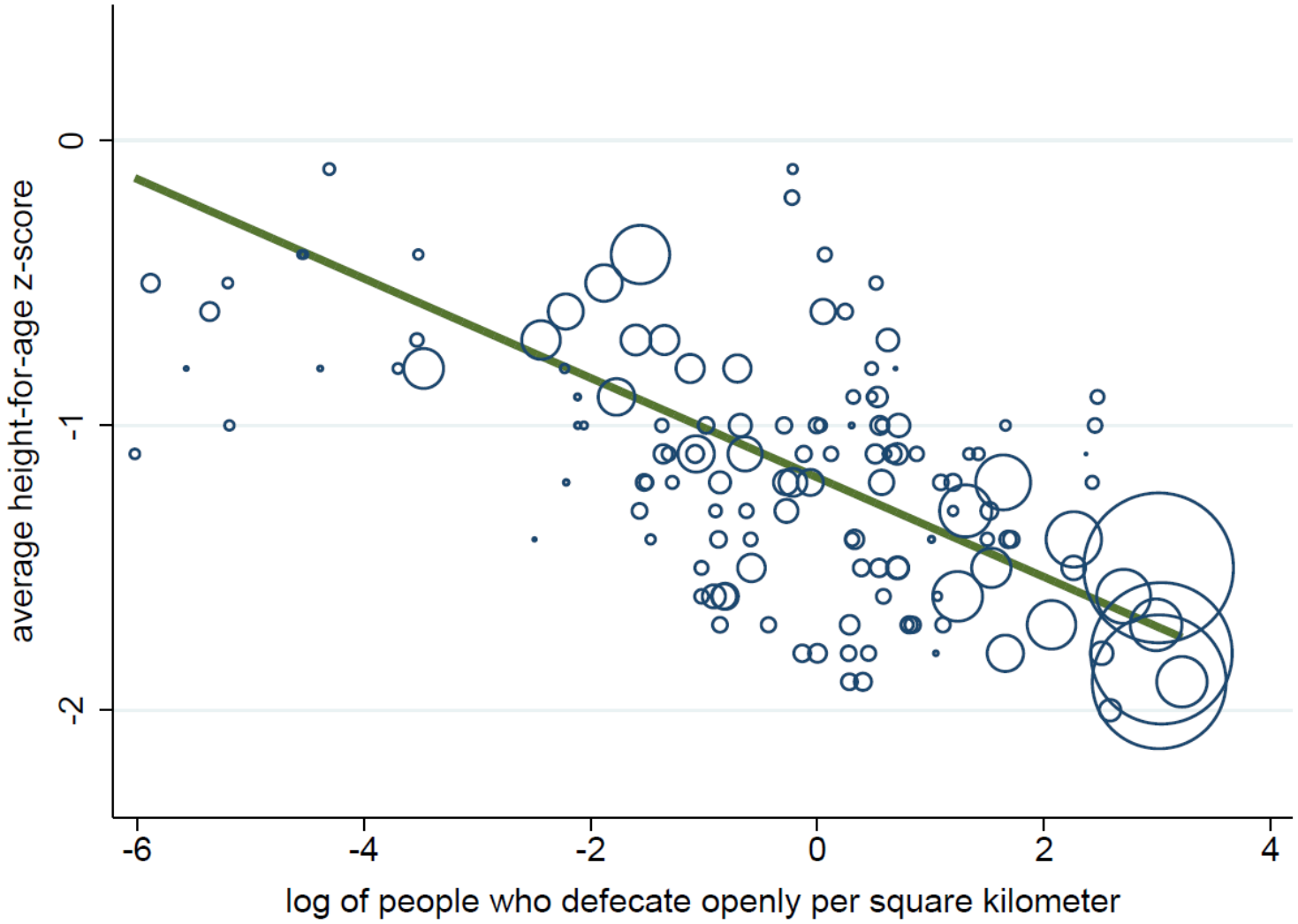
open defecation and child height



open defecation and population density



central questions

- is the sanitation-health gradient steeper where population density is higher? if so, by how much?

- how does this influence our thinking about cause and effect?

why does this matter?

- guide policy decisions and investments
- confirm spillover effects for public action
- reinforce open defecation → health mechanism

two strategies

- international strategy, testing for external validity

- fine fixed effects strategy within Bangladesh, looking at change over time in just one place to nail down cause and effect, testing for internal validity

one: global population density, sanitation, and health

international analysis dataset

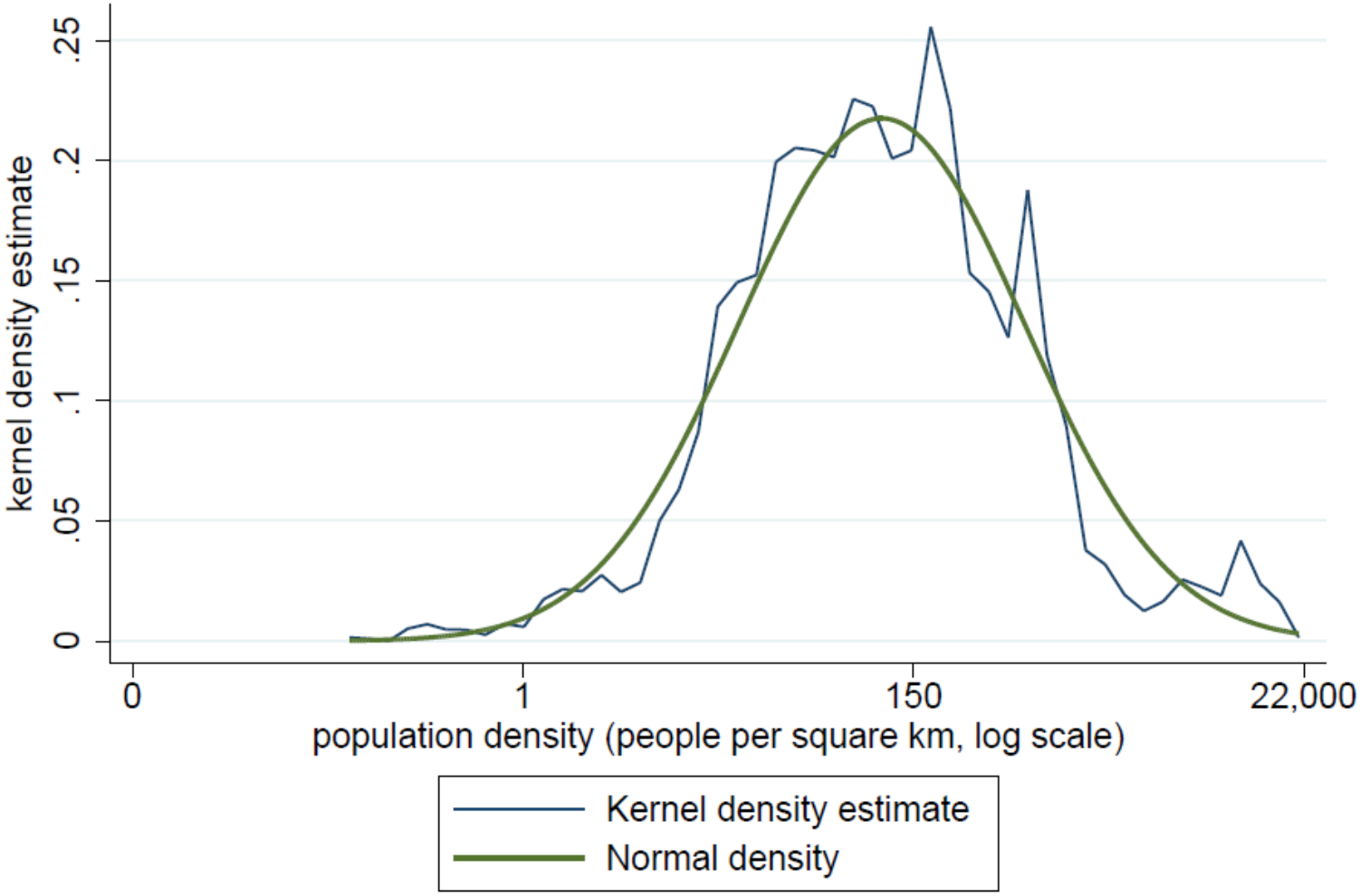
- combine 172 DHS surveys in 68 countries since 1991
- around one million live births
- merge with population density at level of sub-national region (1,800 of these)

international summary

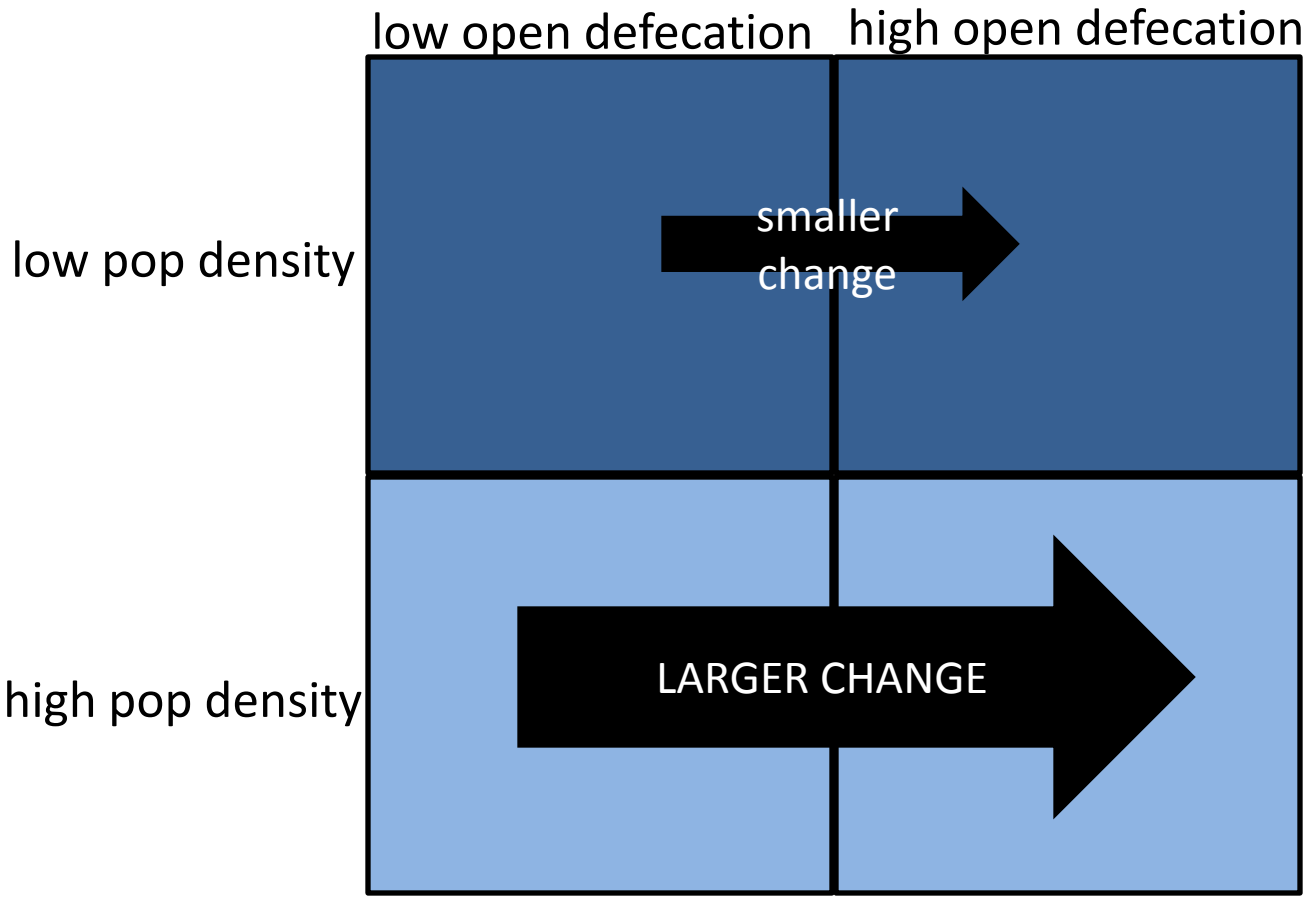
	mean	25th percentile	median	75th percentile
infant mortality rate	62.24			
height-for-age	-1.49	-2.59	-1.53	-0.47
local open defecation	0.35	0.00	0.14	0.72
household open defecation	0.35	0	0	1
population density per km^2	443	31	81	239
ln(density)	4.48	3.43	4.39	5.47
GDP per capita (USD)	1,079	324	525	1,249
local piped water	0.28	0	0	0.57
local electrification	0.41	0	0.22	0.92
urban	0.33	0	0	1
n (IMR: live births)	1,112,465			
n (height: children under 5)	858,514			

Observations are individual children born alive. Children are included in the summary statistics sample if they are in either the IMR or the height sample.

distribution of global population density



interaction between sanitation and population density?

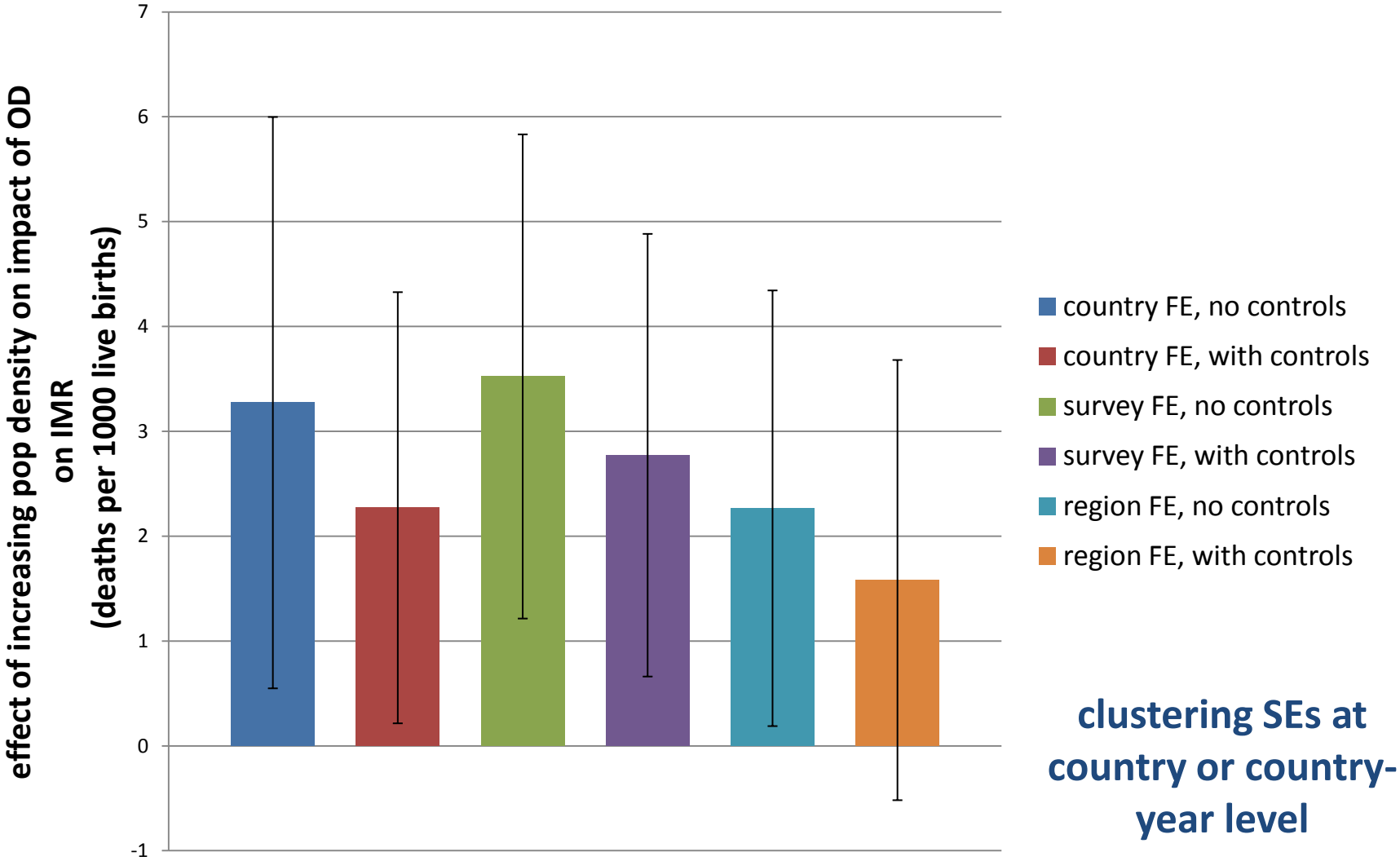


international analysis

- regress health on linear interaction between local sanitation and population density
- control for own household sanitation
- each regression run with and without child-level controls including household assets, birth order, gender, mother's age, household education
- include either
  - country fixed effects
  - survey fixed effects
  - region (i.e. states/provinces) fixed effects

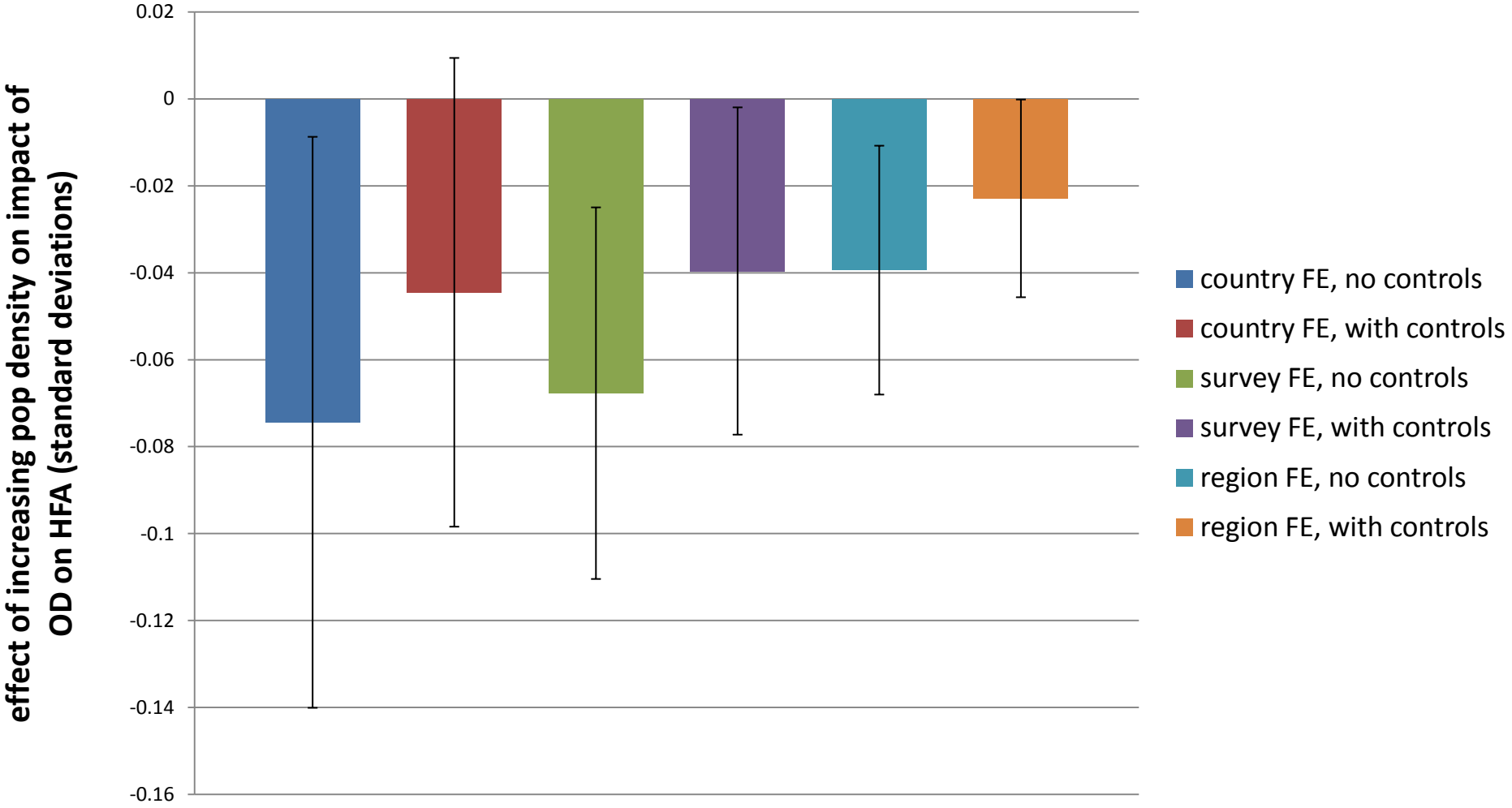
$$health_{ipsc} = \beta_1 local\ OD_{ipsc} \times \ln(density_{psc}) + \beta_2 \ln(density_{psc}) + \beta_3 local\ OD_{ipsc} + \beta_4 household\ OD_{ipsc} + X_{ipsc}\theta + \alpha_{psc} + \varepsilon_{ipsc},$$

regardless of fixed effects/controls, the linear effect of population density on the impact of local open defecation on IMR stays similar globally



clustering SEs at country or country-year level

regardless of fixed effects/controls, the linear effect of population density on the impact of local open defecation on child height stays similar globally

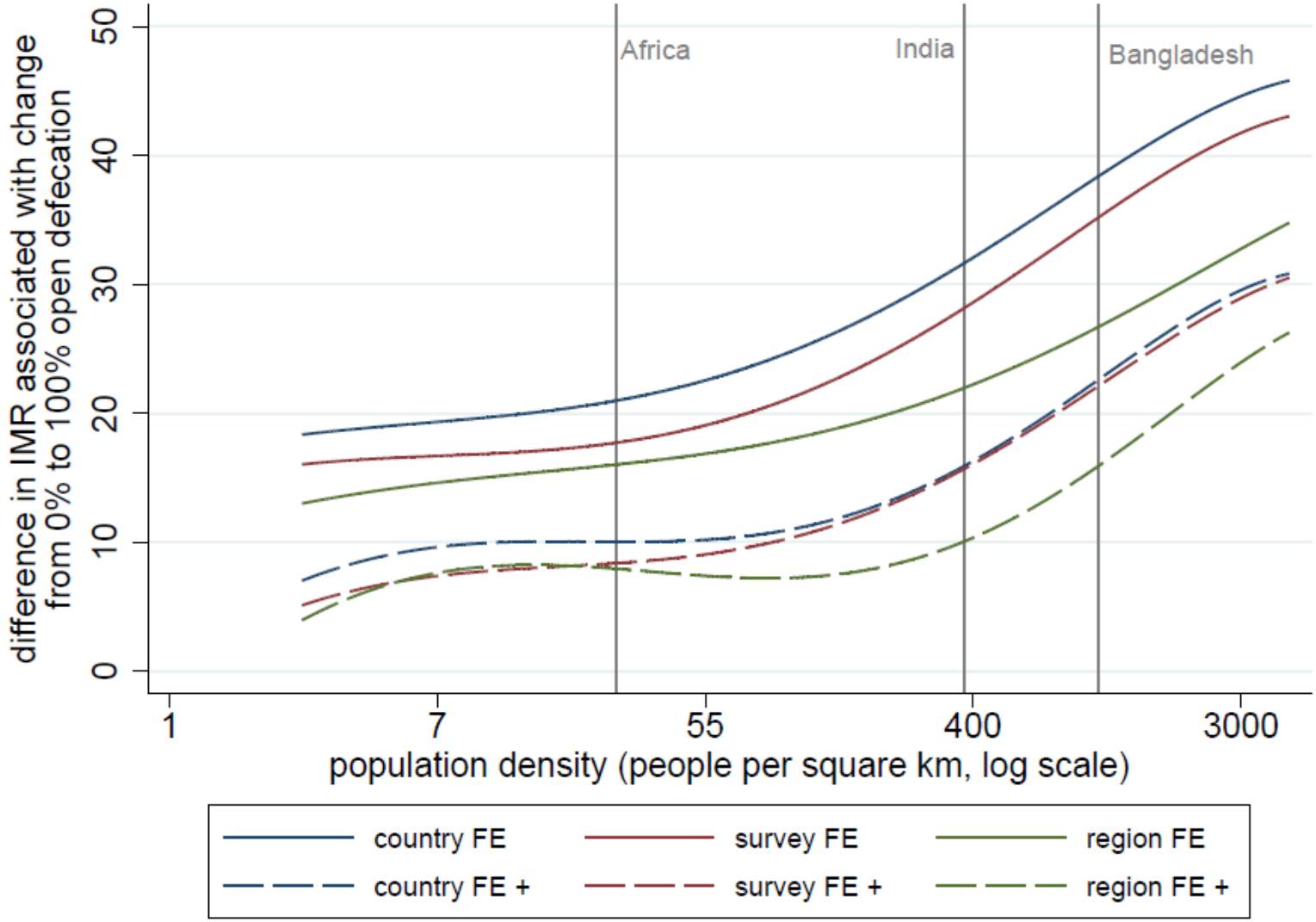


shape of the sanitation-density interaction

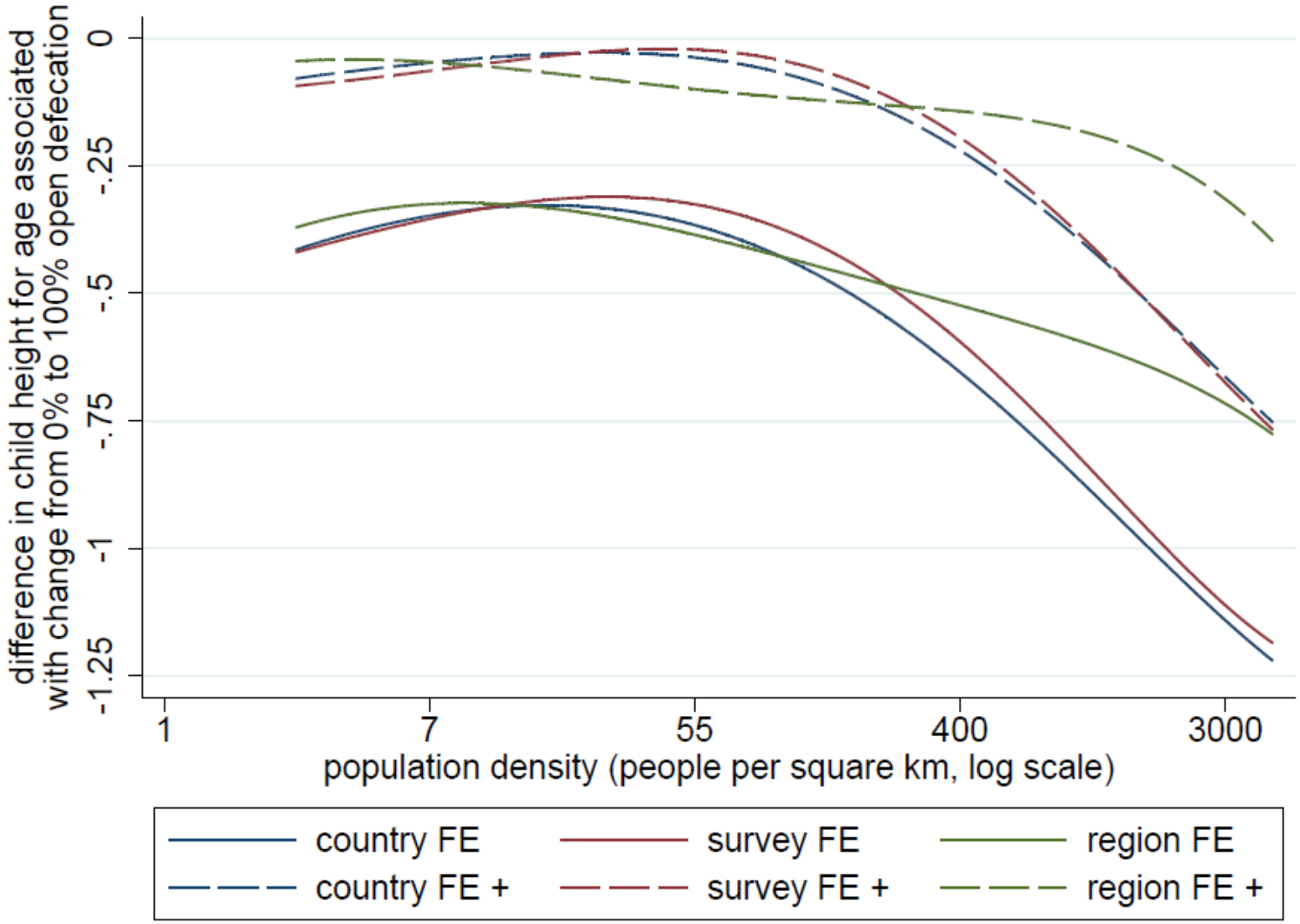
- let's not assume a linear relationship between population and the sanitation-health gradient
- let's allow the data some flexibility and see what shape it takes

$$health_{ipsc} = \alpha_{psc} + \beta_1 local\ OD_{ipsc} + \sum_{j=1}^{5} \beta_{2,j} \ln(density_{psc})^j + \sum_{j=1}^{5} \beta_{3,j} local\ OD_{ipsc} \times \ln(density_{psc})^j + \beta_4 household\ OD_{ipsc} + X_{ipsc}\theta + \varepsilon_{ipsc}.$$

association between local open defecation and IMR, globally

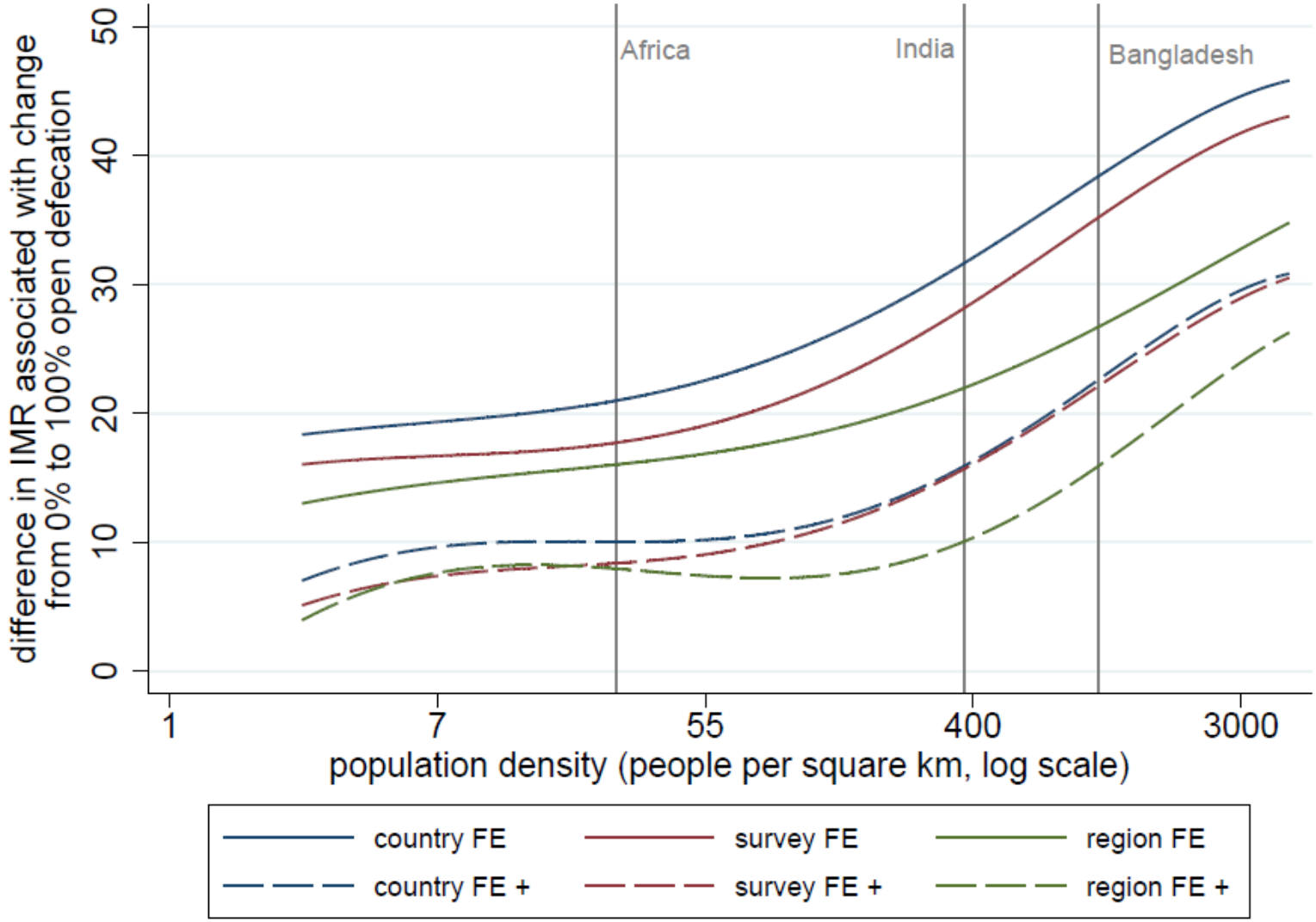


association between local open defecation and child height, globally



the same amount of open defecation is **twice as bad** in a place with a **high population density** average like India versus a low population density average like sub-Saharan Africa

association between local open defecation and IMR, globally



specificity for causation in epidemiology

- is it possible that the interaction between sanitation and population density is just a coincidence?
- bradford hill: specificity is one of several minimum conditions for causality
- is open defecation unique?

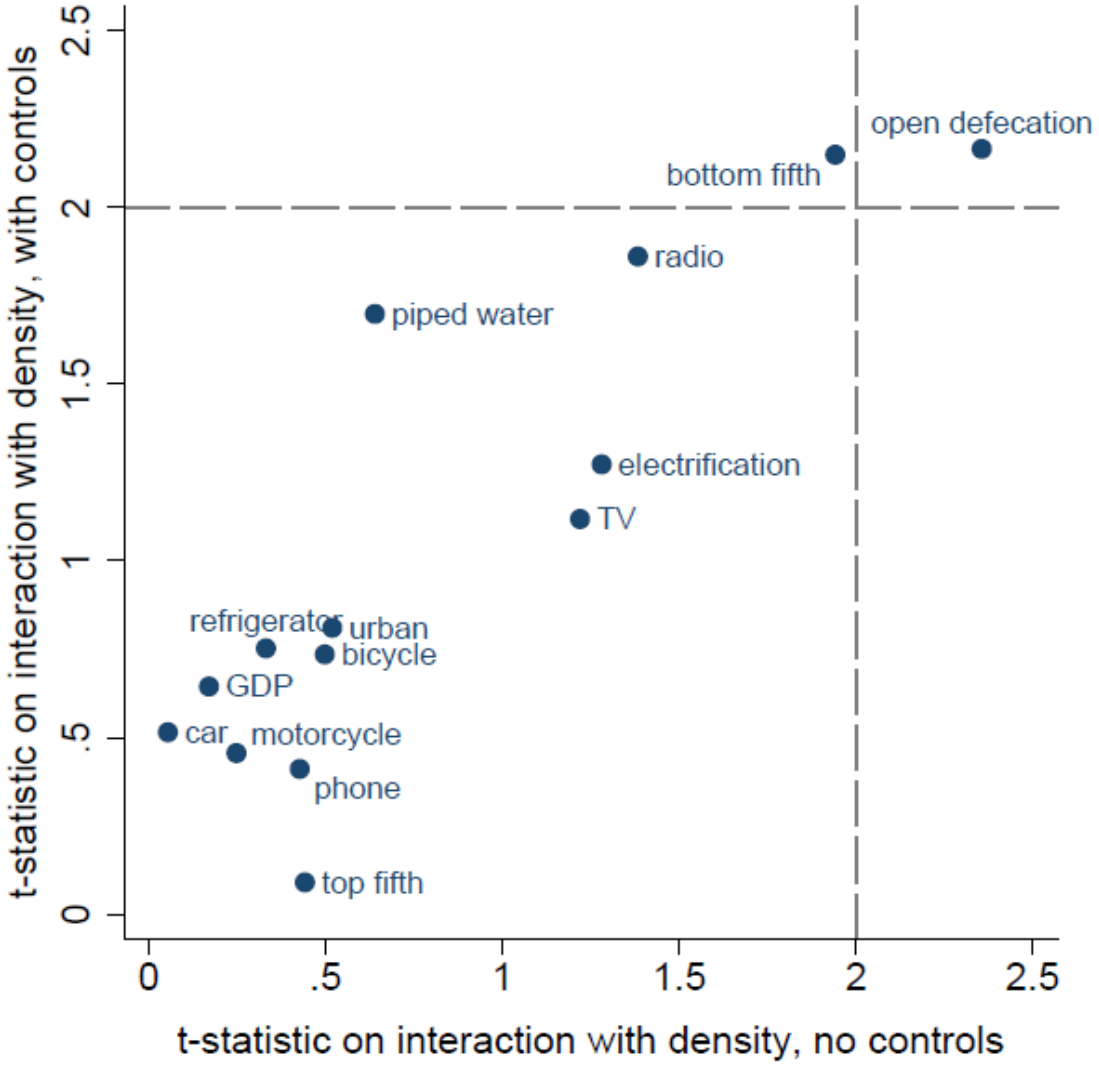
$$IMR_{ipsc} = \beta_0 + \beta_1 SES_{ipsc} + \beta_2 \ln(density_{psc}) + \beta_3 SES_{ipsc} \times \ln(density_{psc}) + \beta_4 household\ OD_{ipsc} + X_{ipsc}\theta + \varepsilon_{ipsc}$$

falsification test

- these are measures of how population density interacts with other local SES variables to predict IMR

- others do not similarly interact with density

- open defecation is unique

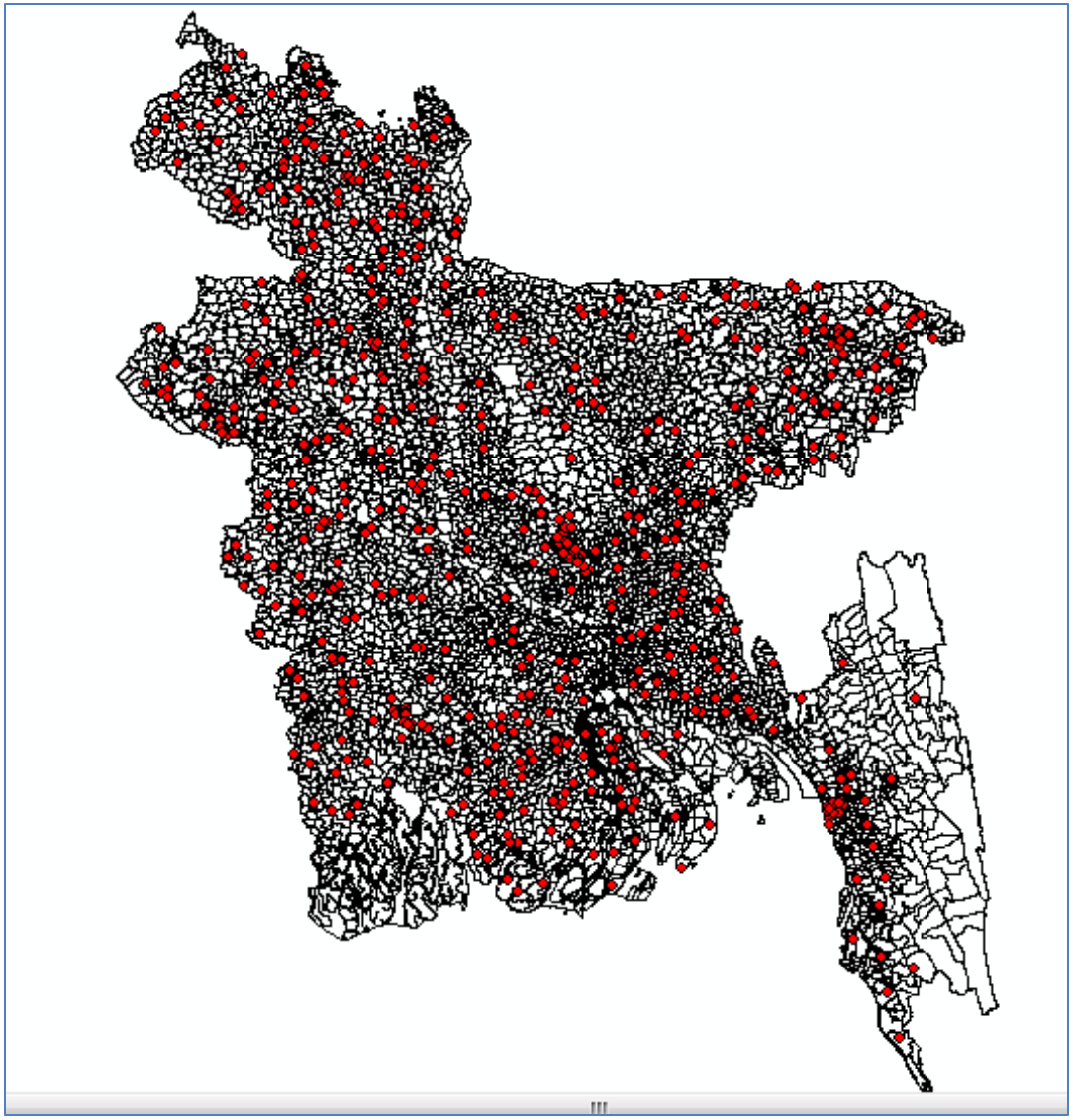


what do we know so far?

- higher pop. density robustly and uniquely associated with steeper sanitation-health gradient
- consistent shape of relationship between OD and health impacts
- association about twice as steep in densely populated areas (i.e. Bangladesh) versus less dense areas (i.e. SSA)

two: population density, sanitation, and health in Bangladesh

GIS matching in Bangladesh



Bangladesh summary

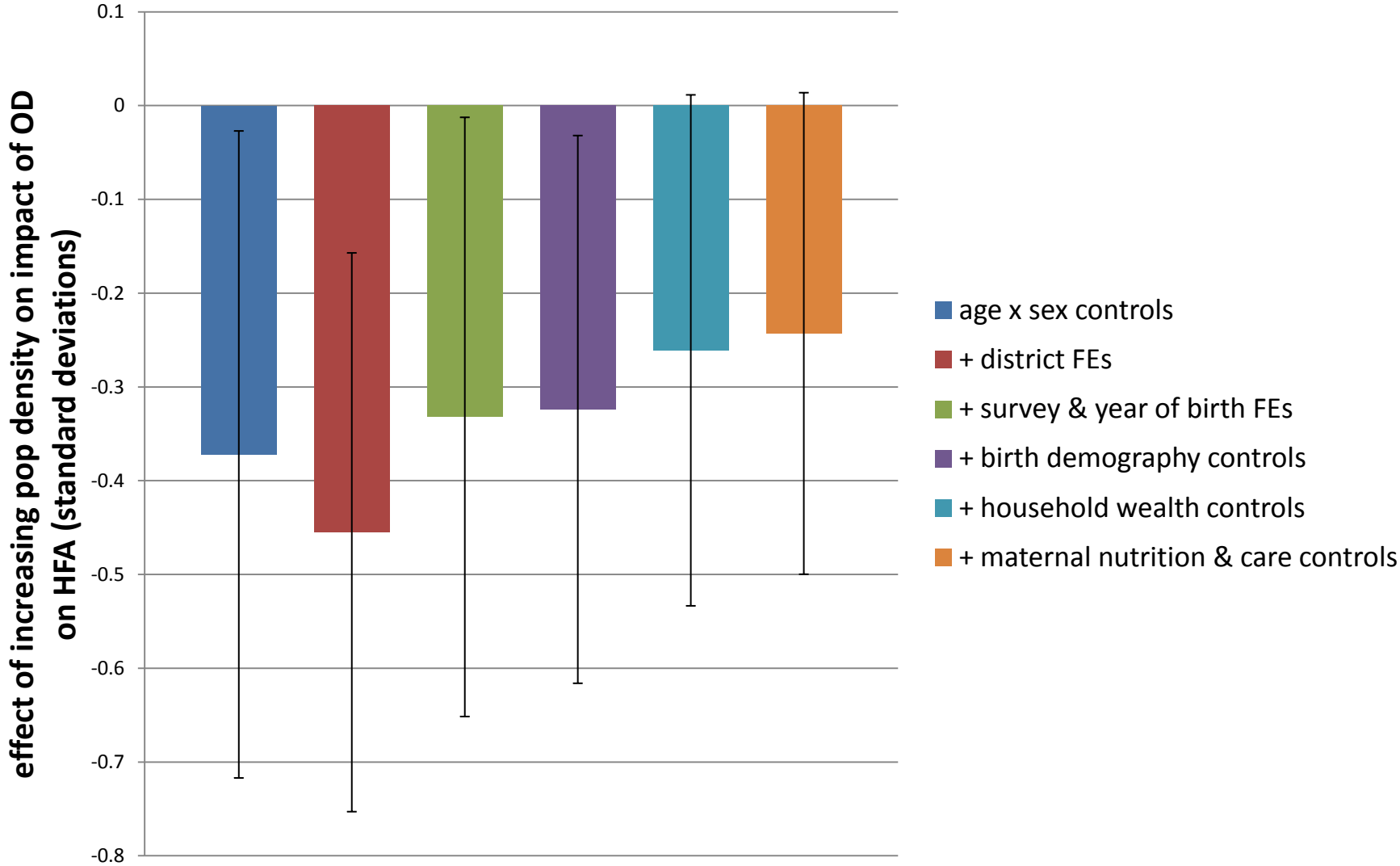
	year		
	1999	2004	2011
height-for-age	-1.95	-1.92	-1.62
IMR	81.57	72.33	50.41
household open defecation	0.199	0.141	0.128
local open defecation	0.201	0.138	0.132
population density per km^2	4,983	4,344	4,466
ln (density)	7.23	7.17	7.29
mother's height (cm)	150	150	151
mother's BMI	20.05	20.22	21.45
mother's age	22.72	22.59	22.43
local radio	0.33	0.32	0.08
local electricity	0.36	0.42	0.60
urban	0.27	0.31	0.31
n (height-for-age)	5,435	5,978	7,743
n (infant mortality)	12,517	12,817	16,902

longitudinal & district-level fixed effects, Bangladesh

- regress child height on linear interaction between local sanitation and population density
- control for own household sanitation and include district and survey round fixed effects
- standard errors clustered by 66 districts
- 120 age-in-months by sex fixed effects and year fixed effects account for overall time trends
- very fine fixed effects

$$height_{idt} = \beta_1 local\ OD_{idt} + \beta_2 \ln(density)_{odt} + \beta_3 local\ OD_{idt} \times \ln(density)_{odt}$$
$$\beta_4 household\ OD_{idt} + X_{idt}\theta + A_{idt} \times sex_{idt} + year_{idt} + \delta_d + \gamma_t + \varepsilon_{idt},$$

regardless of fixed effects/controls, the linear effect of population density on the impact of local open defecation on child height stays similar in Bangladesh



consistency with global estimates

- Bangladesh linear regression:

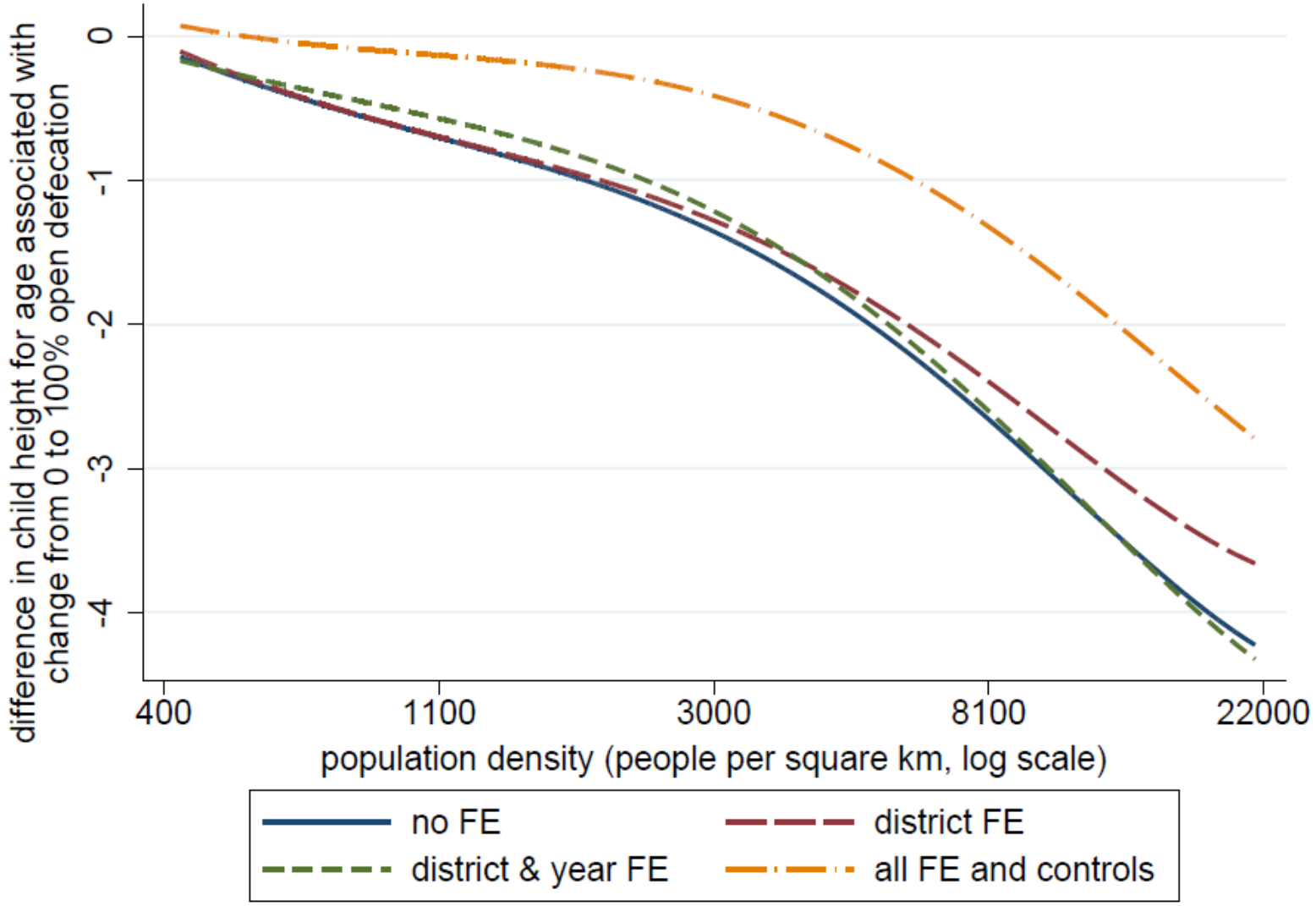
	(1)	(2)	(3)	(4)	(5)	(6)
	height-for-age z-score					
local open defecation	-0.372*	-0.455**	-0.332*	-0.324*	-0.261†	-0.243†
× ln(density)	(0.176)	(0.152)	(0.163)	(0.149)	(0.139)	(0.131)

- Predictions for Bangladesh for non-linear global HFA model:

	predicted sanitation-density interaction		
fixed effects:	country FEs	survey FEs	region FEs
with controls	-0.233	-0.228	-0.309
without controls	-0.186	-0.143	-0.215

The table reports numerical predicted values for the local open defecation × ln(density) interaction term at the average level of population density in Bangladesh, based on the international polynomial model presented in figure 4.

association between local area open defecation and child height, Bangladesh



three: recap

population density matters

- two different methods give same conclusion: sanitation is even more important for early life health where population density is greater
- policy implication: concentrate attention on reducing open defecation where population density is high (whether urban or rural)

thank you!