Growth lost to smoke: Household air pollution, stunting, and wasting of children in India

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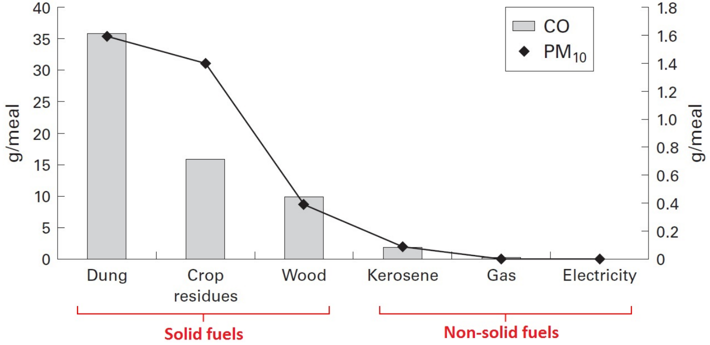
Solid fuels and household air pollution (HAP)

- Solid fuels are used as main energy source for cooking and heating by about half of the world population (Legros et al., 2009; Rehfuess et al., 2006; Smith et al., 2004);
- Fuel combustion releases fine particulate matter, carbon monoxide, benzene, formaldehyde, and other pollutants into the surrounding air (Smith, 2000);
- Distinct fuel types can lead to significantly different levels of HAP (Smith et al., 2011);
  - **Solid fuels**: charcoal and coal, wood products, agricultural crop residue, and animal dung;
  - **Non-solid sources**: electricity, liquefied petroleum gas (LPG), biogas, kerosene.
- Solid fuels used in traditional stoves tend to be much more polluting than non-solid sources (Smith, 2000).

Solid fuels and household air pollution (HAP)

HAP from fuel combustion depends on: source, time since generation, stove type, and ventilation practices.



HAP intensity by fuel type from average time of one meal cooking in an unvented space (Smith et al., 2000).

Exposure to solid fuel smoke

a)

b)

a): Women and children receive the highest exposure to smoke from burning solid fuels as they spend most time in or near the cooking place.
b): HAP concentrations often reach very high levels, well above that of the dirtiest cities.

Source: WHO Guidelines for Indoor Air Quality, 2012.

HAP and Health

- Over four million people worldwide die prematurely each year due to HAP (Greenstone et al., 2015; Lim et al., 2012);
- Main channel is through HAP's contribution to **acute respiratory infections** (Yu, 2011; Prasad et al., 2012; Upadhyay et al., 2015);
- Among the affected populations, **children** are especially at high risk
  - Developing immune system
  - Long hours indoors and often close to the fire, where it is warm and mothers can tend to both them and food at the same time (Mishra and Retherford, 2007).

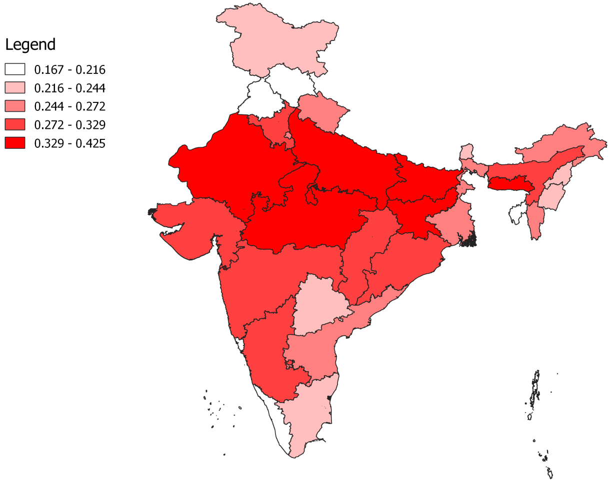
This paper

- Aims to understand the link between **HAP** and **growth deficiencies** in children.
- Data from the 2015-2016 Indian National Family Health Survey (NFHS-4).
- In India:
  - HAP is a major health concern across the entire population, and ranks third in risk factors for disease, behind high blood pressure and high blood sugar (Forouzanfar et al., 2015).
  - In 2016, out of the 155 million children worldwide with chronically impaired growth, India accounted for 48 million (31%) (UNICEF et al., 2017; Save the Children, 2017).
- Standard growth metrics used in the literature: stunting and wasting
  - Computing Z-scores of height and weight

$$\text{Z-score}_i = \frac{\text{Measured Value}_i - \text{Median}(\text{reference population}_{\text{Age,Gender}})}{\text{Standard Deviation}(\text{reference population}_{\text{Age,Gender}})}$$

  - **Stunted**: height-for-age score more than two standard deviations below zero.
  - **Wasted**: weight-for-age score more than two standard deviations below zero.
  - In 2016, 38.4% of Indian children were stunted (down from 48% in 2006) and 21% wasted (up from 19.8% in 2006) (NFHS-4 India Fact Sheet, 2017).

State-level prevalence of stunting 2015-2016 (NFHS-4)



Growth deficiency as public health concern

Short-term	
- Weaker immune systems and higher risk of infection	- Schlaudecker et al. (2011); Rodríguez et al. (2011); Tomkins (1988)
- Lower cognitive development	- Brown and Pollitt (1996); Pollitt et al. (1995)
- Adverse educational achievements	- Hoddinott et al. (2013); Maluccio et al. (2009) Victora et al. (2008); Grantham-McGregor et al. (2007)
- Higher mortality rates	- Olofin et al. (2013); Caulfield et al. (2004)
Long-term	
- Short stature as an adult	- Gigante et al. (2009); Sachdev et al. (2005)
- Functional limitations, reduced work capacity	- Spurr (1988)
- Higher risks of obesity and chronic diseases	- Barker (1994)
- Lower income and fewer assets	- Hoddinott et al. (2008); Victora et al. (2008)
- Poorer marriage outcomes	- Hoddinott et al. (2013)
- Lower birthweight of offsprings, having firstborns at younger ages, and more pregnancies and children.	- Victora et al. (2008); Hoddinott et al. (2013)

HAP and growth deficiencies

- Respiratory infections lead to the activation of the immune system to fight off disease-causing agents.
- This consumes metabolic energy, which will no longer be available for other functions of the metabolism.
- Child growth can be impaired (Schlaudecker et al., 2011).
- Reinforcing loop between growth deficiency and infectious diseases, with one weakening the body and predisposing it to the other and vice-versa (Schlaudecker et al., 2011; Rodríguez et al., 2011).

HAP and growth deficiencies in the literature

Mishra and Retherford (2007):

- Multinomial logistic regression approach, 1998-1999 Indian NFHS-2;
- 37% of severe stunting cases may be due to exposure to solid fuel smoke.

Machisa et al. (2013)

- Multinomial logistic regression approach, 2005-2006 Swaziland Demographic and Health Survey (DHS);
- No significant evidence of a negative impact of solid fuels on stunting.

Fenske et al. (2013)

- Additive quantile regression, 2005-2006 Indian NFHS-3;
- Children from households that use gas or electricity as primary source for cooking to be at lower risk of stunting; impact of solid fuel seems to be strongest in the lower 15% percentile of the height-for-age distribution.

Our contribution

- Specific focus on link between HAP and growth deficiencies while controlling for other factors
  - Discussion of the physiological channel
- Account for endogeneity:
  - Fuel type is not randomly assigned to households;
  - It represents a choice influenced by numerous factors that are also likely to impact child health;
  - Poor households might be more likely to choose free or cheap fuel sources (like dung or wood gathered from nearby fields or forests) and have stunted children;
  - Controlling for household wealth with proxies from available data is likely to reduce bias, but not eliminate it, as the drivers of stunting are numerous.
- Approach:
  - Instrumental variables: Accessibility to clean fuel as an instrument for non-solid fuel use.

Estimation

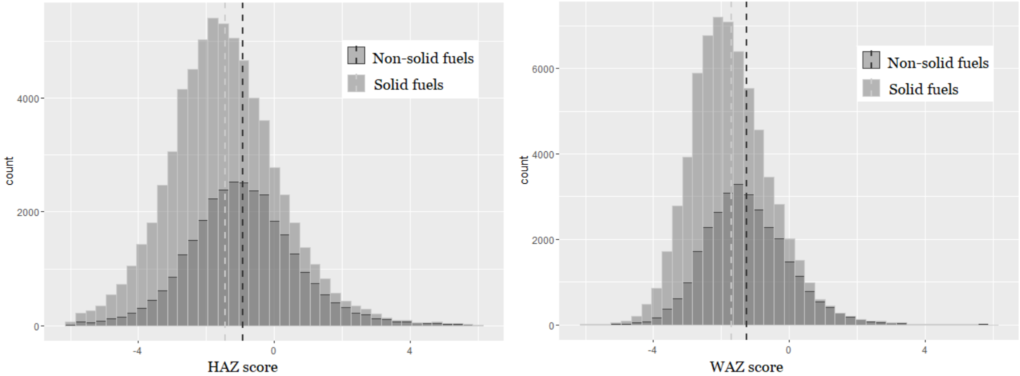
$$\mathrm{GI}_i = \beta_0 + \beta_1 \mathrm{SolidFuel}_i + \beta_2 X_i + \varepsilon_i$$

where:
GI_i = child growth indicator;
$\mathrm{SolidFuel}_i$ = indicator variable of whether the household uses solid fuels as main energy source;
X_i = matrix of other regressors;
Instrument for $\mathrm{SolidFuel}_i$ = household accessibility to clean fuel; depends on the share of households in a PSU that uses solid fuels.

Data

- **Source:** India's National Family Health Survey 2015-2016 (NFHS-4)
- Data from a total of 259,494 children
  - Fuel price data, household income, and secondary choice of fuel not available
- **Sample:** 71,591 Indian children in the age group 0-59 months
  - Only rural households included
  - Missing many observations on child nutrition, mother's BMI and height, and number of vaccinations

Preview of the HAP - Growth relation



Distribution of HAZ (left) and WAZ (right) scores by fuel type for children 5 years old and younger in our sample (N = 94,135 children). The vertical dashed lines indicate subsample means.

Results 1: LPM/OLS models of child growth indicators

	Stunted	Severe	HAZ	Wasted	Severe	WAZ
A. Household characteristics						
Solid fuel use indicator	0.026^a	0.014^a	-0.103^a	0.025^a	0.010^a	-0.078^a
	(0.005)	(0.004)	(0.019)	(0.006)	(0.003)	(0.014)
Separate kitchen indicator	-0.009^b	-0.005	0.029^b	-0.008^b	-0.008^a	0.022^b
	(0.004)	(0.003)	(0.015)	(0.004)	(0.003)	(0.010)
No. of household members	-0.003^a	-0.002^a	0.011^a	-0.003^a	-0.001	0.008^a
	(0.001)	(0.001)	(0.002)	(0.001)	(0.000)	(0.002)
Hindu indicator	0.004	0.002	-0.008	0.013^b	0.016^a	-0.027^c
	(0.006)	(0.004)	(0.019)	(0.006)	(0.004)	(0.014)

Notes: 71,591 observations.

Results 1: LPM/OLS models of child growth indicators

	Stunted	Severe	HAZ	Wasted	Severe	WAZ
B. Child characteristics						
Age (months)	0.004^{a}	0.002^{a}	-0.021^{a}	0.004^{a}	0.001^{a}	-0.013^{a}
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male indicator	0.017^{a}	0.008^{a}	-0.103^{a}	0.007^{b}	0.005^{b}	-0.048^{a}
	(0.003)	(0.003)	(0.011)	(0.003)	(0.002)	(0.008)
Multiple births indicator	0.107^{a}	0.069^{a}	-0.447^{a}	0.117^{a}	0.082^{a}	-0.400^{a}
	(0.020)	(0.016)	(0.067)	(0.020)	(0.015)	(0.051)
Birth order	0.018^{a}	0.012^{a}	-0.059^{a}	0.018^{a}	0.010^{a}	-0.046^{a}
	(0.001)	(0.001)	(0.005)	(0.001)	(0.001)	(0.003)
No. of vaccinations	-0.001	-0.001^{a}	-0.006^{a}	0.002^{a}	-0.000	-0.007^{a}
	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.001)
Breast-fed enough	-0.033^{a}	-0.019^{a}	0.132^{a}	-0.022^{a}	-0.004	0.059^{a}
	(0.006)	(0.005)	(0.020)	(0.006)	(0.004)	(0.015)
Has varied diet indicator	-0.090^{a}	-0.041^{a}	0.410^{a}	-0.145^{a}	-0.056^{a}	0.464^{a}
	(0.004)	(0.003)	(0.015)	(0.004)	(0.003)	(0.011)

Notes: 71591 observations.

Note: $71,591$ observations

Results 2: IV models of child growth indicators

	Stunted	Severe	HAZ	Wasted	Severe	WAZ
A. Household characteristics						
Solid fuel use indicator	0.128^{a}	0.149^{a}	-0.261	0.100^{b}	0.086^{a}	-0.230^{b}
	(0.049)	(0.039)	(0.175)	(0.048)	(0.033)	(0.117)
Separate kitchen indicator	-0.006	-0.001	0.025	-0.006	-0.006^{b}	0.018^{c}
	(0.004)	(0.003)	(0.015)	(0.004)	(0.003)	(0.011)
No. of household members	-0.004^{a}	-0.004^{a}	0.013^{a}	-0.004^{a}	-0.002^{b}	0.011^{a}
	(0.001)	(0.001)	(0.004)	(0.001)	(0.001)	(0.002)
Hindu indicator	0.001	-0.002	-0.003	0.011^{c}	0.013^{a}	-0.021
	(0.006)	(0.004)	(0.020)	(0.006)	(0.004)	(0.014)

Notes: 71, 591 observations. First-stage F-statistic is 1376.775.

Results 2: IV models of child growth indicators

	Stunted	Severe	HAZ	Wasted	Severe	WAZ
B. Child characteristics						
Age (months)	0.004[a]	0.002[a]	-0.021[a]	0.004[a]	0.001[a]	-0.013[a]
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male indicator	0.017[a]	0.008[a]	-0.103[a]	0.007[b]	0.005[b]	-0.048[a]
	(0.003)	(0.003)	(0.011)	(0.003)	(0.002)	(0.008)
Multiple births indicator	0.108[a]	0.071[a]	-0.448[a]	0.118[a]	0.083[a]	-0.401[a]
	(0.020)	(0.016)	(0.067)	(0.019)	(0.015)	(0.050)
Birth order	0.019[a]	0.012[a]	-0.060[a]	0.019[a]	0.011[a]	-0.047[a]
	(0.001)	(0.001)	(0.005)	(0.001)	(0.001)	(0.003)
No. of vaccinations	-0.001	-0.001[b]	-0.006[a]	0.002[a]	-0.000	-0.007[a]
	(0.001)	(0.000)	(0.002)	(0.000)	(0.000)	(0.001)
Breast-fed enough	-0.035[a]	-0.021[a]	0.134[a]	-0.022[a]	-0.005	0.061[a]
	(0.006)	(0.005)	(0.020)	(0.006)	(0.004)	(0.015)
Has varied diet indicator	-0.090[a]	-0.042[a]	0.410[a]	-0.145[a]	-0.056[a]	0.464[a]
	(0.004)	(0.003)	(0.015)	(0.004)	(0.003)	(0.011)

Notes: 71,591 observations. First-stage F-statistic is 1376.775.

Interventions

- Ventilation
  - Awareness
  - Access
- Cleaner fuels and more efficient cookstoves
  - Improving health and reducing emissions

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