Cooking Fuel Choice and Child Mortality in India

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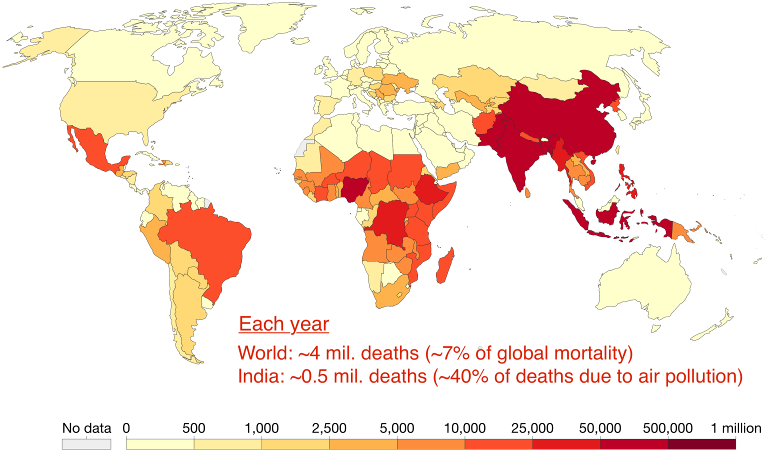
Outline

Motivation

Number of deaths from household air pollution, 2017

Annual number of premature deaths attributed to illness as a result of household air pollution from the use of solid fuels for cooking and heating.

Our World in Data



<u>Each year</u>

World: ~4 mil. deaths (~7% of global mortality)

India: ~0.5 mil. deaths (~40% of deaths due to air pollution)

Source: IHME, Global Burden of Disease

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  - $\sim$3 billion people (or 41% of the world population) use open fire or traditional cooking stoves (WHO 2018).

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  - ∼3 billion people (or 41% of the world population) use open fire or traditional cooking stoves (WHO 2018).
- Under-five mortality incidence has been a subject of interest in the air quality-mortality relationship research.
  - The most vulnerable members of the society closely exposed to IAP.

Main Objective

- Provide population-based estimate on the causal impact of indoor air pollution, defined as use of polluting fuels for cooking, on child mortality (under-five, child, infant, post-neonatal, and neonatal)

Epidemiological or Medical Literature:

- A rich literature found a strong and adverse health impact of IAP:
  - +200 publications (Zhang and Smith 2007) such as Naz et al. (2015, 2016) and more
- However, they are questioned due to:
  - inadequate controls for health outcomes
  - lack of convincing identification strategy

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  - inadequate controls for health outcomes
  - lack of convincing identification strategy

Economic Literature:

- The socio-economic analysis for this problem is relatively new among social scientists.
  - Duflo et al. (2008)[improved cookstoves and smoke exposure/health outcomes in Orissa, India]
  - Smith-Sivertsen et al. (2009), Diaz et al. (2007)[improved cookstoves and exposure to IAP/health outcomes in San Marcos, Guatemala]
  - Hanna et al. (2016)[Improved cookstoves and smoke exposure in Orissa, India]
  - Imelda (2020)[LPG stoves and child mortality in Indonesia]

Contributions

- Use cooking fuels as an indirect measure of IAP to provide empirical evidence on its impact on child mortality
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  - Previous papers mainly focused on cookstoves as a measure of IAP
- The first analysis to take into account endogeneity, among studies where indoor air quality is proxied by cooking fuels
- Utilized the nationally representative demographic survey data, DHS, which covers households from all 36 states and 640 districts of India

Indoor Air Quality and Infant Mortality in India

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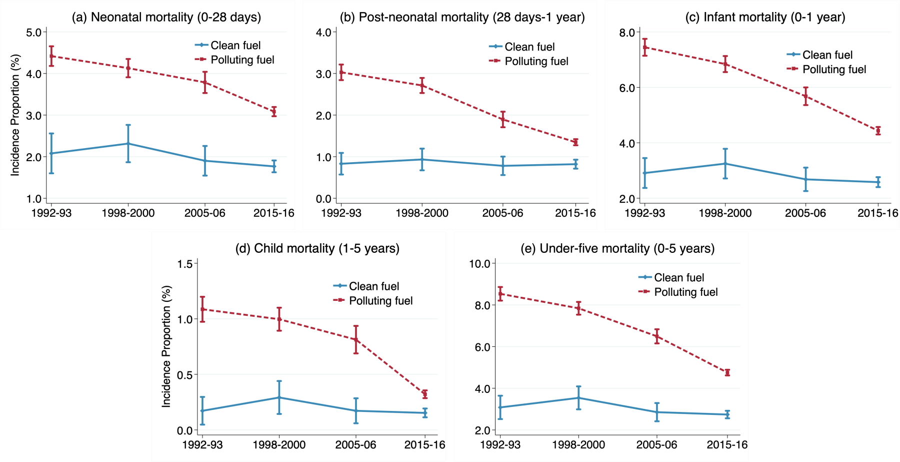
- 24-hour average of PM_{10} concentration in those solid fuel firing households (Smith 2000)
  - 2,000 $\mu g/m^3 >> 150$ $\mu g/m^3$ (US EPA standards for PM_{10})
- 20% of deaths among under-five children is attributed to the use of solid fuels (Bassani et al. 2010, Upadhyay et al. 2015)

Infant Mortality Trends in India



Preview of Main Findings

- Highly heterogeneous local mortality effects by children's age (neo-natal), gender (girls) and household characteristics (5-6 adult members).

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- Highly heterogeneous local mortality effects by children's age (neo-natal), gender (girls) and household characteristics (5-6 adult members).

- Infant mortality rates increase by approximately 4 percentage points due to polluting fuel use for cooking ($=$ 27 under-five infants per 1,000 live births lost economy-wide).

Empirical Strategy

- Indoor air quality and Infant mortality relationship:

$$
\begin{aligned}
\mathit{Child\ Mortality}_{ihdst} = \alpha + \beta \mathit{Polluting\ Fuel}_{hdst} + \mathit{Household}_{hdst}\boldsymbol{\gamma} + \\
+ \mathit{Mother}_{ihdst}\boldsymbol{\lambda} + \mathit{Child}_{ihdst}\boldsymbol{\delta} + \mathit{District}_{dst}\boldsymbol{\pi} + \\
+ \eta_{st} + \varepsilon_{ihdst},
\end{aligned}
$$

- Indoor air quality (cooking fuel choice) and infant mortality are determined simultaneously:

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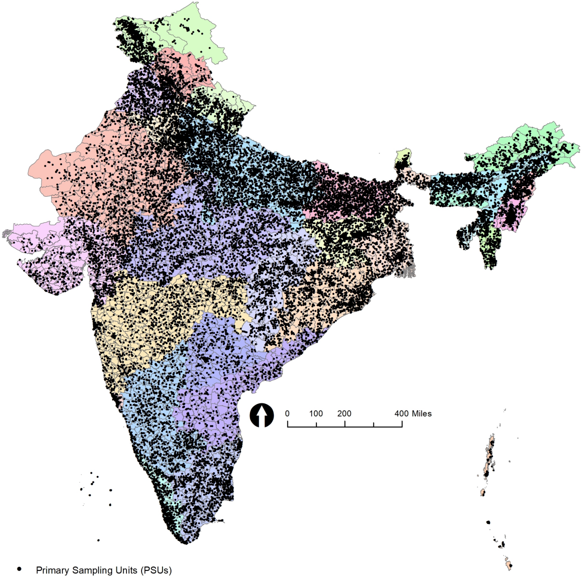
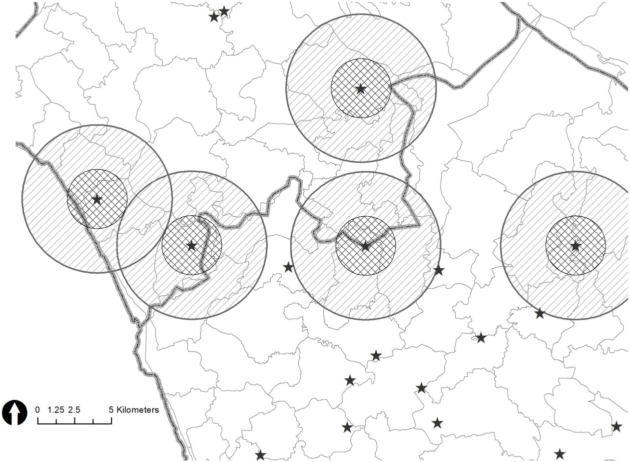
- First stage specification:

$$\begin{aligned} \textit{Polluting Fuel}_{hdst} = \textit{Household}_{hdst}\boldsymbol{\gamma} + \textit{Mother}_{ihdst}\boldsymbol{\lambda} + \textit{Child}_{ihdst}\boldsymbol{\delta} + \\ + \textit{District}_{dst}\boldsymbol{\pi} + \eta_{st} + \xi_{ihdst} \end{aligned}$$

Distribution of PSUs in India's DHS-4



Displacement of PSU Points in DHS-4



★ Primary Sampling Units (PSUs) -- Villages/Towns
PSU Location Buffer (within 2 kilometers)
PSU Location Buffer (within 5 kilometers)
Boundaries of Villages/Towns in State of Kerala
Boundaries of Sub-Districts in State of Kerala

Data

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  - India's DHS: 1992–93, 1998–99, and 2015–16
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- Other controls
  - Place of residence, household income, household size, place where food is cooked, type of house, mother's age, mother's education, gender of child, breastfeeding status,
- Instrumental variables
  - *Forest cover*: Land covered by forests (as % of geographical area)
  - *Ag. land ownership*: Whether household owns agricultural land (dummy)

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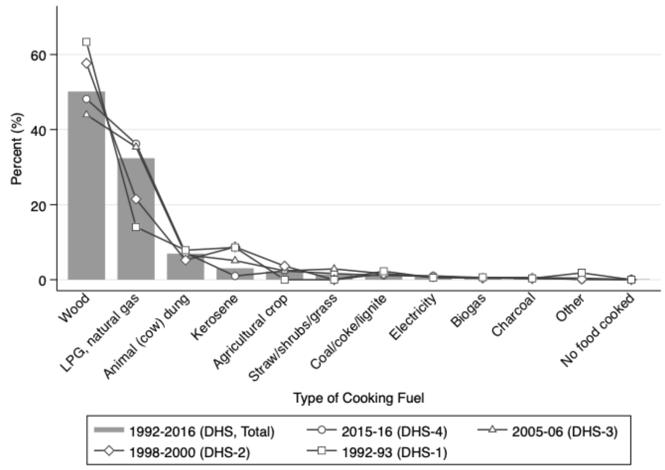
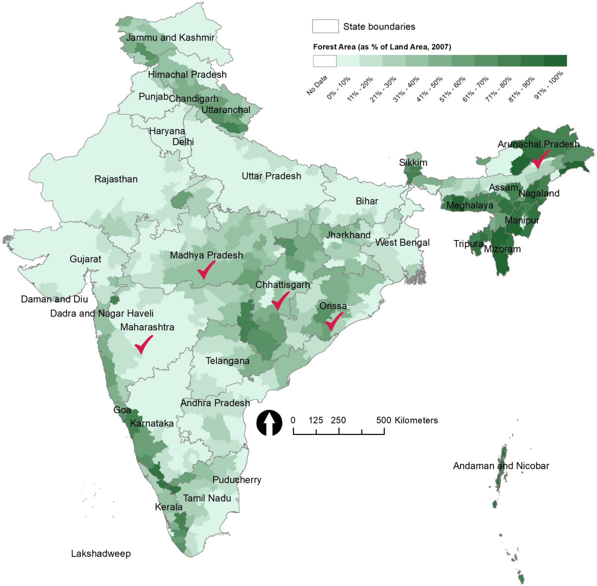
- Exclusion restriction
  - Zero-First-Stage Test
  - There is no accompanying direct effect of forest condition and agricultural land ownership on under-five mortality
    - ✓ Correlation: $\rho^{agland}_{under5} = 0.0038$ & $\rho^{forest}_{under5} = -0.0137$

- Partial monotonicity (Mogstad, Torgovitsky, and Walters, 2021)
  - The correlation between each instrument and the treatment is positive and statistically significant.
  - Partial correlation between the two instruments is essentially zero.
  - Formal test: The null hypothesis of negative weights is strongly rejected ($p = 0.000$), and the null hypothesis of positive weights is not rejected ($p = 1.000$).

Share of Households relying on Different Types of Fuels

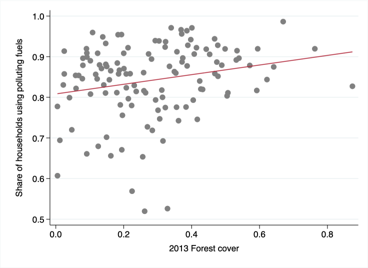


India’s Forest Cover

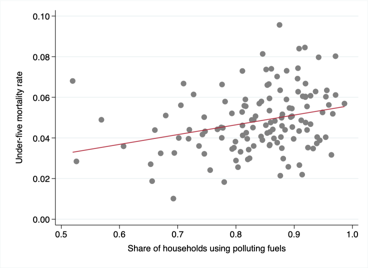


Relationship between Forest Cover, Fuel Choice, and Under-Five Mortality

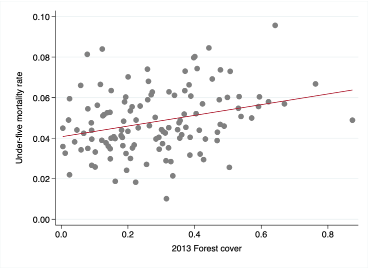
(a) Forest - Polluting fuel



(b) Polluting fuel - U5 mortality



(c) Forest - Under-five mortality



IV: Mortality on Polluting Fuel [1]

	1^{st} stage	2^{nd} stage				
	(1)	(2)	(3)	(4)	(5)	(6)
	Polluting/Biomass fuel use	Under-five (0-5 years)	Child (1-5 years)	Infant (0-1 year)	Post-neonatal (28 days-1 year)	Neonatal (0-28 days)
	Panel A. Indoor air pollution = Polluting fuel					
Polluting fuel for cooking		0.040**[**]	-0.001	0.041**[**]	0.011	0.030**[**]
		(0.020)	(0.005)	(0.019)	(0.011)	(0.015)
		[0.018]	[0.005]	[0.017]	[0.010]	[0.014]
Forest cover	0.065***					
	(0.022)					
Owns agricultural land	0.054***					
	(0.003)					
Observations	194254	194254	194254	194254	194254	194254
R^2	0.53	0.02	0.00	0.02	0.01	0.01
Montiel Olea-Pflueger weak IV test						
Effective F-statistic ($\alpha = 5\%$)	54.12					
Critical value 2SLS ($\tau = 10\%$)	17.41					
Hansen J statistic		1.70	0.33	2.18	0.40	2.29
Degree of overidentification		1.00	1.00	1.00	1.00	1.00
p-value of Hansen J statistic		0.19	0.57	0.14	0.53	0.13

	1st stage	2nd stage				
	(1)	(2)	(3)	(4)	(5)	(6)
	Polluting/Biomass fuel use	Under-five (0-5 years)	Child (1-5 years)	Infant (0-1 year)	Post-neonatal (28 days-1 year)	Neonatal (0-28 days)
		Panel B. Indoor air pollution = Biomass fuel				
Biomass fuels for cooking		0.037*[**]	-0.001	0.037**[**]	0.011	0.026*[**]
		(0.019)	(0.005)	(0.018)	(0.010)	(0.014)
		[0.015]	[0.004]	[0.015]	[0.008]	[0.012]
Forest cover	0.067***					
	(0.022)					
Owns agricultural land	0.058***					
	(0.003)					
Observations	189384	189384	189384	189384	189384	189384
R^2	0.55	0.02	0.00	0.02	0.01	0.01
Montiel Olea-Pflueger weak IV test						
Effective F-statistic ($\alpha = 5\%$)	57.82					
Critical value 2SLS ($\tau = 10\%$)	17.74					
Hansen J statistic		1.74	0.58	2.40	0.44	2.54
Degree of overidentification		1.00	1.00	1.00	1.00	1.00
p-value of Hansen J statistic		0.19	0.45	0.12	0.51	0.11

IV Probit: Mortality on Polluting Fuel

	1^{st} stage	2^{nd} stage				
	(1)	(2)	(3)	(4)	(5)	(6)
	Polluting fuel use	Under-five	Child	Infant	Post-neonatal	Neonatal
Polluting fuel for cooking		0.456**	-0.141	0.501**	0.362	0.502**
		(0.210)	(0.574)	(0.213)	(0.324)	(0.238)
Forest cover	0.065***					
	(0.009)					
Owns agricultural land	0.054***					
	(0.002)					
Observations	194254	194254	192079	194254	193859	194254
R^2	0.53					
Montiel Olea-Pflueger weak IV test						
Effective F-statistic ($\alpha = 5\%$)	272.04					
Critical value 2SLS ($\tau = 10\%$)	8.27					
Model Wald χ^2		3855.19	395.07	3669.80	1463.43	2499.14
Model degrees of freedom	20.00	53.00	46.00	53.00	52.00	53.00
Model Wald p-value	0.00	0.00	0.00	0.00	0.00	0.00
Exogeneity test Wald p-value		0.09	0.69	0.06	0.34	0.10
Wald χ^2 test of exogeneity		2.90	0.16	3.57	0.92	2.75

IV: Dirtiness of Polluting Fuels

	1^{st} stage	2^{nd} stage				
	(1)	(2)	(3)	(4)	(5)	(6)
	Polluting fuel use	Under-five	Child	Infant	Post-neonatal	Neonatal
Dirtiness level of cooking fuels		0.007**	-0.000	0.007**	0.002	0.005**
		(0.003)	(0.001)	(0.003)	(0.002)	(0.002)
Forest cover	0.191***					
	(0.051)					
Owns agricultural land	0.343***					
	(0.014)					
Observations	194254	194254	194254	194254	194254	194254
R^2	0.52	0.02	0.00	0.02	0.01	0.01
Montiel Olea-Pflueger weak IV test						
Effective F-statistic ($\alpha = 5\%$)	273.62					
Critical value 2SLS ($\tau = 10\%$)	6.10					
Hansen J statistic		0.89	0.23	1.20	0.22	0.99
Degree of overidentification		1.00	1.00	1.00	1.00	1.00
p-value of Hansen J statistic		0.34	0.63	0.27	0.64	0.32

Heterogeneity by Household Size

- Non-IV estimation results suggests that household size is negatively associated with child mortality for all five age groups
- Three potential channels through which household size might guide household's cooking fuel choice, burden of cooking, and childcare for mothers
    i. A smaller household may find it easier to switch to cleaner fuel - LPG as an example - since pre-fabricated gas stoves limit the size of cooking utensils that can be used
    ii. A larger household size may arguably relieve some of the burden of cooking or childcare on mothers and mitigate the child's mortality risk due to IAP
    iii. If cooking outdoors is more practical for a larger household, then a child's exposure to IAP will also decrease
        - ✓ Household size is in fact negatively correlated with cooking in a separate building (ρ: -0.003, SE: 0.002, p-value: 0.162) and outdoors (ρ: -0.005, SE: 0.002, p-value: 0.027)

Heterogeneity by Household Size [1]

	1^{st} stage	2^{nd} stage				
	(1) Polluting fuel use	(2) Under-five	(3) Child	(4) Infant	(5) Post-neonatal	(6) Neonatal
	Panel A. Number of household members = [1-4]					
Polluting fuel for cooking		0.221***	0.011	0.210***	0.082**	0.127**
		(0.066)	(0.017)	(0.064)	(0.035)	(0.051)
Forest cover	0.082***					
	(0.025)					
Owns agricultural land	0.035***					
	(0.004)					
Observations	48777	48777	48777	48777	48777	48777
R^2	0.58	-0.00	0.00	-0.00	-0.01	0.01
Montiel Olea-Pflueger weak IV test						
Effective F-statistic ($\alpha = 5\%$)	22.87					
Critical value 2SLS ($\tau = 10\%$)	14.65					
Hansen J statistic		5.08	0.58	6.49	5.46	2.98
Degree of overidentification		1.00	1.00	1.00	1.00	1.00
p-value of Hansen J statistic		0.02	0.44	0.01	0.02	0.08

	1^{st} stage	2^{nd} stage				
	(1)	(2)	(3)	(4)	(5)	(6)
	Polluting fuel use	Under-five	Child	Infant	Post-neonatal	Neonatal
	Panel B. Number of household members = [5-8]					
Polluting fuel for cooking		0.059**	0.002	0.056**	0.008	0.048***
		(0.023)	(0.006)	(0.022)	(0.012)	(0.018)
Forest cover	0.070***					
	(0.022)					
Owns agricultural land	0.054***					
	(0.003)					
Observations	109747	109747	109747	109747	109747	109747
R^2	0.53	0.01	0.00	0.01	0.00	0.00
Montiel Olea-Pflueger weak IV test						
Effective F-statistic ($\alpha = 5\%$)	48.60					
Critical value 2SLS ($\tau = 10\%$)	16.57					
Hansen J statistic		1.96	0.03	2.12	0.31	2.20
Degree of overidentification		1.00	1.00	1.00	1.00	1.00
p-value of Hansen J statistic		0.16	0.86	0.15	0.58	0.14

Heterogeneity by Household Size [3]

	1^{st} stage	2^{nd} stage				
	(1) Polluting fuel use	(2) Under-five	(3) Child	(4) Infant	(5) Post-neonatal	(6) Neonatal
	Panel C. Number of household members = [9-12]					
Polluting fuel for cooking		-0.023	-0.001	-0.022	-0.020	-0.002
		(0.036)	(0.008)	(0.035)	(0.018)	(0.030)
Forest cover	0.021					
	(0.032)					
Owns agricultural land	0.069***					
	(0.007)					
Observations	28278	28278	28278	28278	28278	28278
R^2	0.52	0.01	0.00	0.01	0.00	0.01
Montiel Olea-Pflueger weak IV test						
Effective F-statistic ($\alpha = 5\%$)	37.02					
Critical value 2SLS ($\tau = 10\%$)	10.41					
Hansen J statistic		0.06	0.40	0.01	0.92	0.62
Degree of overidentification		1.00	1.00	1.00	1.00	1.00
p-value of Hansen J statistic		0.80	0.53	0.92	0.34	0.43

Heterogeneity by Child's Gender

- Previous studies suggest that there is a significant preference for sons in India (Arnold et al. 1998, Jayachandran and Pande 2017, Jayachandran 2023)
- There are two possibilities:
  i. Polluting fuels for cooking could have more adverse effects on boys' health if the only source of differential treatment comes from parents spending more time caring for sons than daughters, including time spent near cooking locations.
  ii. There are multiple sources of differential treatment by child's gender, including for example medical treatment, or pollution exposure adjustment if respiratory diseases do arise.
- The mortality effect we observe sums up the combined outcomes of pollution exposure and ex post medical treatment and/or exposure adjustments.

Heterogeneity by Child's Gender [1]

	1^{st} stage	2^{nd} stage				
	(1) Polluting fuel use	(2) Under-five	(3) Child	(4) Infant	(5) Post-neonatal	(6) Neonatal
	Panel A. Boys					
Polluting fuel for cooking		0.009	-0.006	0.015	-0.005	0.021
		(0.027)	(0.006)	(0.026)	(0.014)	(0.022)
Forest cover	0.058**					
	(0.023)					
Owns agricultural land	0.058***					
	(0.003)					
Observations	101309	101309	101309	101309	101309	101309
R^2	0.54	0.02	0.00	0.02	0.01	0.01
Montiel Olea-Pflueger weak IV test						
Effective F-statistic ($\alpha = 5\%$)	55.64					
Critical value 2SLS ($\tau = 10\%$)	16.66					
Hansen J statistic		1.17	1.18	1.84	0.13	1.92
Degree of overidentification		1.00	1.00	1.00	1.00	1.00
p-value of Hansen J statistic		0.28	0.28	0.17	0.72	0.17

Heterogeneity by Child's Gender [2]

	1^{st} stage	2^{nd} stage				
	(1) Polluting fuel use	(2) Under-five	(3) Child	(4) Infant	(5) Post-neonatal	(6) Neonatal
	Panel B. Girls					
Polluting fuel for cooking		0.078***	0.005	0.073***	0.032**	0.041**
		(0.026)	(0.008)	(0.025)	(0.016)	(0.020)
Forest cover	0.072***					
	(0.022)					
Owns agricultural land	0.050***					
	(0.003)					
Observations	92945	92945	92945	92945	92945	92945
R^2	0.53	0.01	0.00	0.01	0.00	0.01
Montiel Olea-Pflueger weak IV test						
Effective F-statistic ($\alpha = 5\%$)	45.27					
Critical value 2SLS ($\tau = 10\%$)	16.29					
Hansen J statistic		1.11	0.17	1.02	0.55	0.48
Degree of overidentification		1.00	1.00	1.00	1.00	1.00
p-value of Hansen J statistic		0.29	0.68	0.31	0.46	0.49

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- Consumer credit initiatives like the Sales Offers for Improved Cookstoves in Uganda and Pay-as-you-Go LPG in Kenya.

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- The mortality effect is also concentrated:
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  - Among relatively small households with limited scope for the division of labor between childcare and cooking responsibilities