HARVARD ENVIRONMENTAL ECONOMICS PROGRAM

Research Workshop
for
Pre-Doctoral Fellows and Alumni

Thursday-Friday, September 19 – 20, 2019
Harvard Kennedy School
Cambridge, Massachusetts

Columbia World Projects
COLUMBIA UNIVERSITY

Clean Household Energy for Public Health in Ghana

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Household Air Pollution

Nearly 3 billion people use traditional cookstoves and fuels.

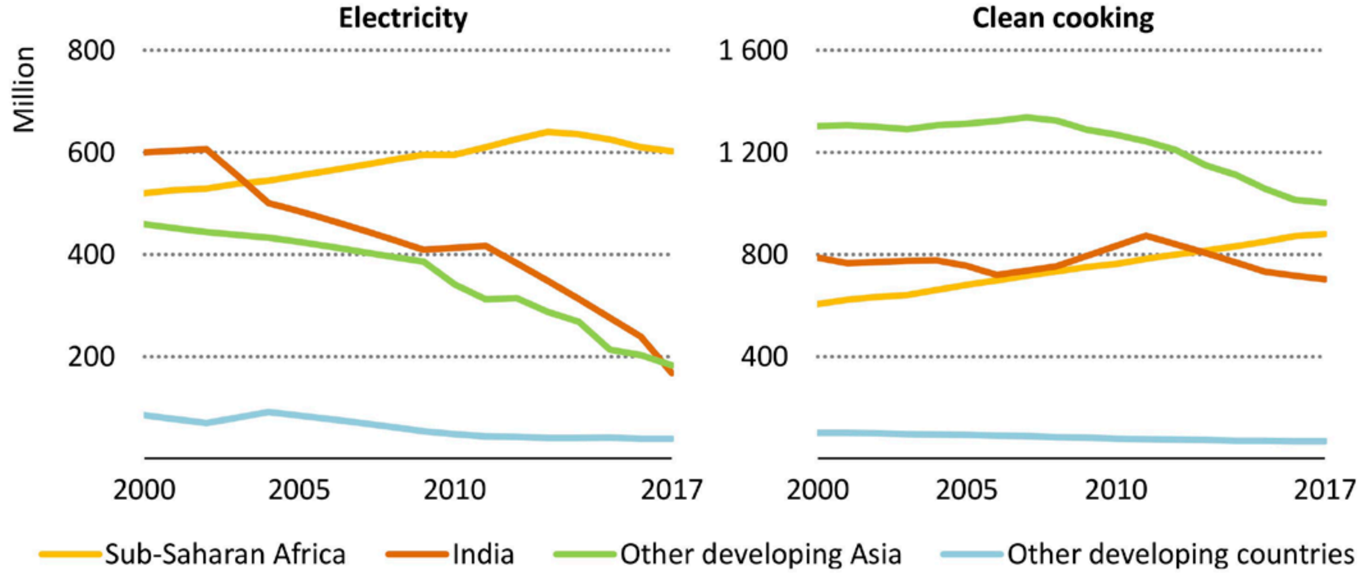
- WHO estimates that 3.8 million preventable air pollution-related deaths occur each year from polluting cookstoves[1]
- Burning biomass, typically used for cooking, contributes to about 25% of the world's black carbon emissions annually[2]

In sub-Saharan Africa, biofuels account for over 60% of overall energy consumption,[3] and the population with no access to clean cooking is increasing.[4]

Over the last 15 years, this issue has had a day in the sun - significant investment in clean cookstoves

- Most of these interventions have failed, in two ways
  - Limited adoption and sustained use of clean technologies
  - Air pollution exposures remain high, even when the adoption/use hurdle is cleared
- LMICs that have made significant progress have used very large clean fuel subsidies (Ecuador, Indonesia, Morocco)

Figure 2.7 ▷ Population without modern energy access



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IEA 2018 World Energy Report

Traditional Cooking in Ghana

In Ghana, ~70% of households cook with biomass.[5]

- **Health.** Human exposure to air pollution increases risk of early childhood pneumonia, lung cancer, chronic pulmonary obstructive disease (COPD), & cardiovascular disease. HAP exposure is top risk factor for death and disability.[6]
- **Deforestation & forest degradation.** Fuelwood harvesting in excess of sustainable growth is a leading cause of deforestation.
- **Climate change.** Cookstoves emit CO_2, methane, and black carbon, all of which are greenhouse pollutants.
- **Poverty and gender inequality.** Collecting fuelwood and cooking over an open fire is time-consuming and a physically strenuous activity, which falls primarily on women and children.

Strong government commitment to household energy transitions – 50% by 2030 – but no real sense of what to do

12 yrs of collaboration w/ Ghana MOH

- Ghana Randomized Air Pollution and Health Study (GRAPHS): Large scale randomized controlled trial assessing air pollution exposure and health impacts
- Enhancing LPG Adoption in Ghana (ELAG): RCT assessing barriers to LPG adoption (transportation costs; health information)
- Program evaluation of Ghana MOE household energy interventions
- Health effects of air pollution exposure
    - Lung function
    - Epigenetic modification
    - Microbiome
    - Neurodevelopment

Project Structure: Assess, Design, and Test

Phase I (Years 1 – 2): Assessment of needs and opportunities

- Needs assessment: nationally representative household survey
- Exposure assessment: nationally representative air pollution exposure assessment
- Behavioral assessments: how do households make decisions about technology adoption and use? How do they respond to nudges?
- Technology assessment: costs of clean options (LPG, electricity, ethanol, processed biomass pellets); regulatory and infrastructure constraints

Phase II (Years 3 – 5): **Testing at scale**

Deploy the most promising technologies and behavioral interventions in 2 districts – approx. 30,000 people

How does this differ from prior efforts?

- Incorporate behavior change approaches to support adoption and sustained use of clean fuels.
- Develop a stack of clean energy technologies that can (hopefully) fully displace traditional open fires – match technologies to needs.
- Transition entire communities towards clean alternatives.
- Identify broader energy system changes that support and sustain household and community level transitions.

References

1. https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

2. Bond, Tami C., et al. "Bounding the role of black carbon in the climate system: A scientific assessment." *Journal of Geophysical Research: Atmospheres* 118.11 (2013): 5380-5552

3. IEA (2014), Africa Energy Outlook, IEA, Paris (page 37).

4. IEA (2018), World Energy Outlook 2018, IEA, Paris (Figure 2.7, page 96).

5. Asante, Kwaku Poku, et al. "Ghana's rural liquefied petroleum gas program scale up: A case study." *Energy for Sustainable Development* 46 (2018): 94-102.

6. http://www.healthdata.org/ghana

7. IEA (2018), World Energy Outlook 2018, IEA, Paris (page 97).

Raising Wages, Raising Pollution

Unintended environmental consequences of anti-poverty programs

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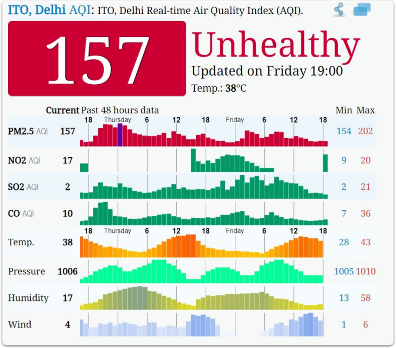
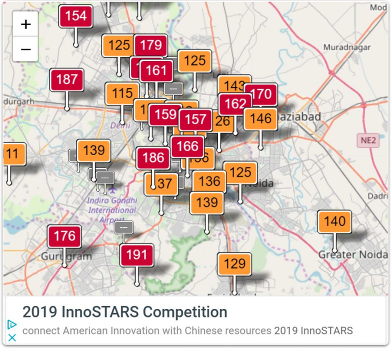
September 20, 2019

Indian air pollution is a public health crisis



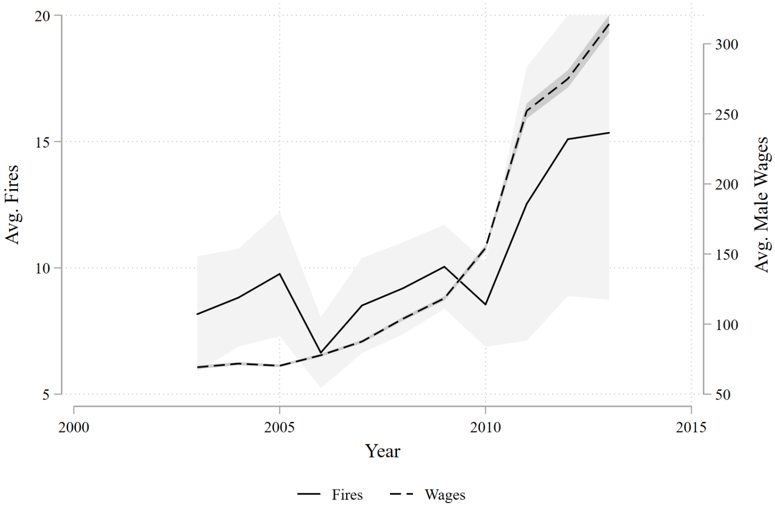


- The EPA recommended level of PM2.5 is 35.
- An estimated 1.24 million additional people died in 2017 as a result of air pollution (Balakrishnan et al, 2019).

Crop residue burning is a major cause of air pollution

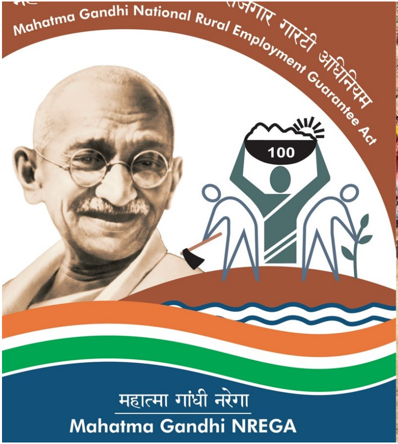

"[L]arge-scale open burning of post-harvest crop residue/wood in nearby rural regions is contributing to severe haze pollution in Delhi during winter and autumn (≈42±17%)." – Bikkina et al, 2019

Wages and fires are correlated over time



Notes: Wage data (right axis) comes from the ICRISAT meso data set and reports annual district level agricultural wages from 2003 to 2012. The average of the count of fires by district and month over the same time period (left axis) is assembled from NASA FIRMS data. FIRMS data is constructed from remote sensing imagery using the MODIS satellites. 95% confidence intervals for the mean of both variables are shown in light grey.

NREGA was a shock to rural, agricultural labor markets



"During interviews some farmers stated that the main reason for the labor shortage is ... the National Rural Employment Guarantee Act (NREGA). This has led to an acute shortage of manpower in the agriculture, industrial and construction sectors across the country." (FLA, 2012)

Research question

Was the increase in agricultural fires driven by changing agricultural production practices in response to higher wages & labor scarcity?

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Proposed Mechanism:
Labor shortages and/or higher wages $\rightarrow$ Increased mechanization (Clemens et al. 2018) $\rightarrow$ Greater residue and more fires

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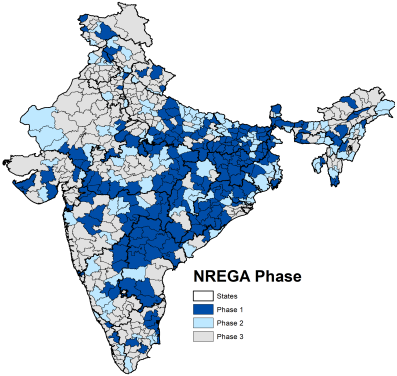
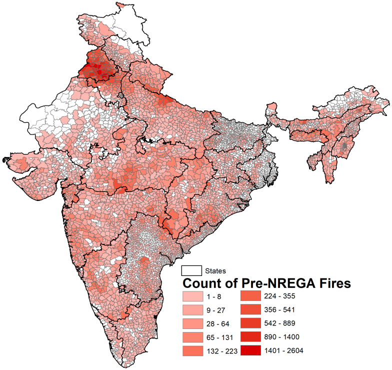
Empirical approach:

1. Utilize the sequential roll-out of NREGA in a diff-in-diff framework (Imbert and Papp 2015; Shah and Steinberg 2015)
2. Verify results using treatment from an RCT improving NREGA implementation (not covered today)

Distribution of Fires and NREGA Roll-out

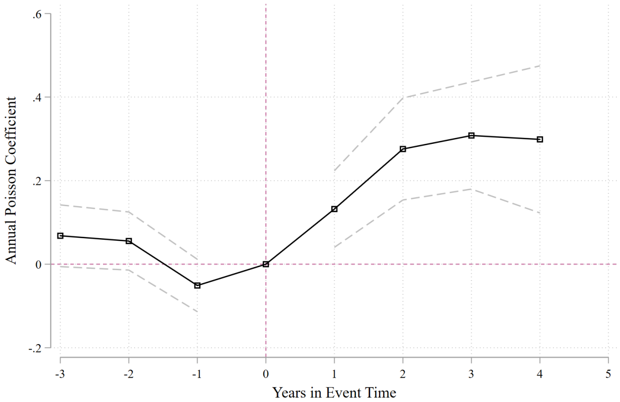


Districts by timing of NREGA roll-out.



Annual average fires as measured by MODIS satellite from 2003-2005 (pre-NREGA).

NREGA Increased Fires



NOTES: Each point is the estimated ω_τ coefficient from the regression $y_{it} = \mathbb{1}_{I_i} \cdot \sum_{\tau \in T} \omega_\tau Y_\tau + \gamma_i + \delta_t$, where $\mathbb{1}_{I_i}$ is an indicator that the district was treated by NREGA. Y_τ is an indicator for event-time year τ in the set $T = \{-3, -2, -1, 0, 1, 2, 3, 4\}$, γ_i is a district fixed effect , δ_{it} is a month $\times$ year fixed effect and ϕ_{it} are weather controls. 95% CIs are shown in grey bars. The figure uses the full sample.

Diff-in-Diff Estimate of Impact

	Cropland Fires	
Post-NREGA	0.096**	0.213***
	(0.044)	(0.051)
Districts	558	558
Months	144	144
N	80,352	80,352
R^2	0.63	0.71
District FE	X	X
Year × Month FE	X	X
Weather Controls		X

NOTES: Each column represents separate regressions. In all columns the outcome is monthly cropland fires. In all columns the base regression is a fixed effects poisson of the form $y_{it} = \beta Post + \psi[Post \times NREGA] + \gamma_i + \delta_t$ where y_{it} is the outcome in district i in month t. Post is a dummy variable equal to one after NREGA treatment takes effect in a given phase and NREGA is a dummy indicating the NREGA phase of district i. γ_i are district fixed effects while δ_t is a year by month fixed effect. In column 2 I include controls for the monthly average cloud cover, precipitation and minimum and maximum temperature in district i in month t. N refers to the number of district × months included in each regression. The sample is a balanced, monthly panel of districts in India from 2003 to 2014. Heteroskedasticity robust standard errors clustered at the district level are in parentheses. (* p<.10 ** p<.05 *** p<.01).

Implementation of NREGA increased fires by ≈ 23% [12%,31%].

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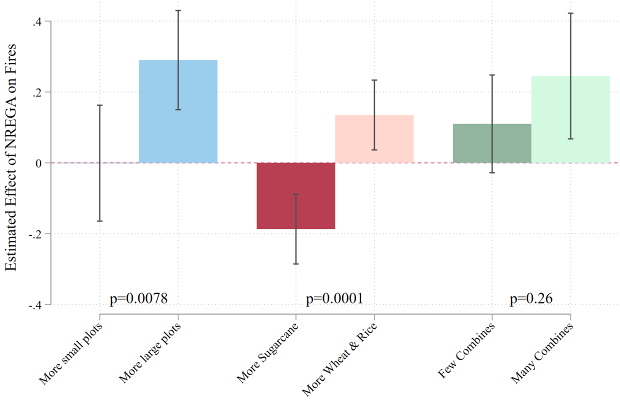
NREGA has a larger impact in areas with easier mechanization



Notes: Each pair of bars comes from a separate regression. Each bar reports the estimated impact of NREGA implementation by sub-sample. The general estimating equation is the poisson fixed effects specification with weather controls. Sub-samples are defined based on the average (a) share of plots within large and small size classes, (b) the area planted in sugarcane and wheat & rice, and (c) number of combines in a district. In all cases the sub-samples are defined based on averages over the period 2003-2005, pre-NREGA. I also report the p value from a test of equality between the coefficients in each pair. Mechanization is easier in places with (a) many large plots, (b) more area in wheat & rice and (c) more combines.

Alternative Explanations?

Consumption/Income Effects: I find no effects on wheat production from NREGA and weakly negative effects on sugarcane production. I find no effect of NREGA on area planted in either wheat or sugarcane. I can reject (at 95%) a change in fires greater than 1.5% due to changes in area planted in wheat. I can reject changes greater than 13% as a result of changes in sugarcane production.

Insurance Effects: Consistent with existing work (Gerhke 2013) that finds that to the extent NREGA changed cropping patterns it induced farmers to crop more high-value crops (i.e. fruits and cotton) for which fires are not used to clear residue.

Estimating the health consequences

- Previous work (Pullabhotla 2018) suggests that increases in PM_{10} of similar magnitude resulted in an increase of deaths of $<$5 year-olds by $\approx$100,000.
- Impacts are concentrated in rural districts that NREGA was intended to help.

Thank you!

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