

Adding Fuel to Fire: Spatial Disparities and Peer Effects in the Adoption of Clean Cooking Fuels in India

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Introduction

Use of solid biomass for cooking is rampant, and is one of the main causes of indoor air pollution and its associated health consequences in developing countries (WHO, February 2016)

- ▶ Global Burden of Disease (2013) report: 2.9 million deaths caused by ambient air pollution due to PM 2.5
- ▶ Estimates suggest that cooking with traditional biomass accounts for almost 18% of greenhouse gas emissions (Bond et al., Global Biogeochemical Cycles (2007))
- ▶ Cleaner alternatives are available, but are relatively more expensive (Liquefied Petroleum Gas, or LPG as a cooking fuel in India)

Background on Cooking Fuel Use in India

- ▶ Fuel choice varies between rural and urban households.
 - ▶ Rural households have strong preferences for biofuels such as firewood, charcoal and agricultural waste
 - ▶ Urban households use LPG or electricity as sources of cooking fuel
- ▶ Focus of this paper is on Liquefied Petroleum Gas (LPG)
 - ▶ LPG is the cheapest "clean" cooking fuel available, but it still remains unaffordable to large segments of Indian society (despite subsidies)
 - ▶ Benefits of subsidies have accrued to richer, urban households in certain states (Gol 2010)
 - ▶ Wide spatial disparities exist: states such as Maharashtra, Andhra Pradesh, Tamil Nadu, Uttar Pradesh and Karnataka received around 50% of the total connections of LPG and almost 50% of the subsidies in 2012-2013

Objective and Literature Review

What factors could determine the adoption and use of LPG as a cooking fuel in India?

- ▶ Role of socio-economic factors in determining clean cooking fuel choice has been extensively studied (Hanna, Duflo and Greenstone (2016) , Lewis and Pattanayak (2012), Reddy (1995), Farsi et. al. (2007), Gupta and Kohlin (2006) and Cheng and Urpelainen (2014))
- ▶ Research emerging from developed countries has shown that social interactions may be the reason for spatial clustering in the adoption of clean technologies (Bollinger and Gillingham (2012), Graziano and Gillingham (2014))
- ▶ Limited developing country literature: (Bandiera and Rosul (2006), Munshi (2004)), Somanathan (2010), Beltram et.al. (2015))
- ▶ **Objective:** To investigate whether information spillovers exist, and how they contribute to the spatial disparities in Indian LPG adoption

Data Description

- ▶ Data: National Sample Survey on Household Consumer Expenditure (Ministry of Statistics and Programme Implementation, GoI) and India Human Development Survey Data (University of Maryland and National Council of Applied Economic Research, India)
- ▶ Thick rounds of NSS survey used for analysis (43rd round (1987-88), 55th round (1999-00), 61st round (2004-05) and 66th round (2009-10)); Two rounds of IHDS (panel) data (2005-06 and 2011-12)
- ▶ Households asked detailed questions about their expenditure on items over a "reference period" (the period of time over which the household is asked to provide information about expenditure: 30 days for cooking fuels, 30/365 days for cook-stoves)
- ▶ Geographical information includes the district and state of residence, and it is possible to identify households that live in the same village/urban block

Proportion of Population Using LPG as the Primary Cooking Fuel (By State) in the Thick Rounds of the NSS

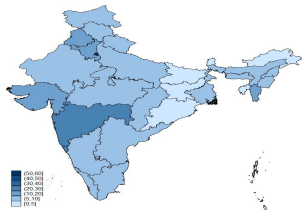


Figure 1: 1987-88

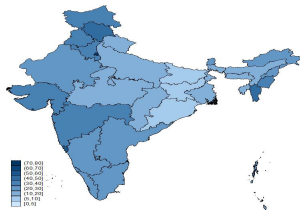


Figure 3: 1999-00

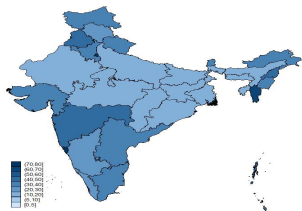


Figure 2: 2004-05

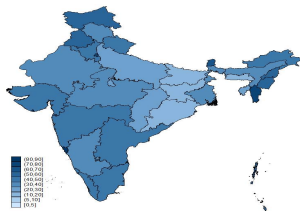


Figure 4: 2009-10

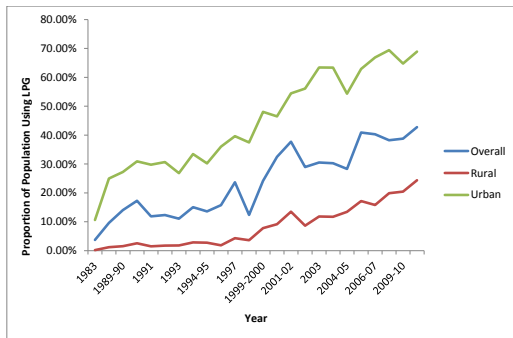
Difference in LPG Adoption Rates Across States

Table 1: Differences in LPG Adoption Rates Between "LPG-Intensive" States and Other States

Round	43			55			61			66		
Year	1987-88			1999-00			2004-05			2009-10		
LPG Adoption Rate	Overall	Urban	Rural	Overall	Urban	Rural	Overall	Urban	Rural	Overall	Urban	Rural
LPG-Intensive States	14.78%	29.72%	2.20%	30.17%	49.07%	10.24%	36.51%	56.91%	18.55%	48.08%	67.97%	28.16%
Other States	7.30%	21.56%	0.84%	21.46%	47.03%	6.86%	25.30%	52.97%	11.95%	35.42%	63.23%	18.19%
Overall Population	9.44%	24.58%	1.16%	23.94%	47.76%	7.65%	28.30%	54.33%	13.42%	38.78%	64.75%	20.45%

Notes: Source: NSS Data. "LPG-intensive" states and union-territories include Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Uttar Pradesh, Delhi and Chandigarh. "Other States" comprises all the other states and union-territories of India.

Evolution of the Proportion of Population Using LPG as the Primary Cooking Fuel from 1983 to 2011-12



Baseline Empirical Estimation Using Cross-Sectional (NSS) Data: Methodology-I

Baseline Instrumental Variable Two-Stage Least Squares (IV-2SLS) Estimation:

$$A_i = \alpha_0 + \alpha_1 A_{-ij} + \alpha_2 X_i + \mu_i \quad (1)$$

- ▶ A_i is the 0/1 dependent variable (is LPG household i 's primary cooking fuel?), A_{-ij} is the average rate of LPG adoption amongst all households in the same village/urban block as household i (excluding household i), and α_1 is the coefficient of interest capturing the marginal effect of an increase of 1 unit in the proportion of households in the same village using LPG on household i 's probability of using LPG.

Baseline Empirical Estimation Using Cross-Sectional (NSS) Data: Methodology-II

Baseline Instrumental Variable Two-Stage Least Squares (IV-2SLS) Estimation:

$$A_i = \alpha_0 + \alpha_1 A_{-ij} + \alpha_2 X_i + \mu_i \quad (2)$$

- ▶ Socio-economic controls - household size, whether it had access to electricity and (free) firewood, closeness to a large urban centre, whether it purchased a cookstove, age, gender and level of education of the head of the household, prices of LPG and kerosene, dummies for income, religion and social group, along with district dummies. Standard errors clustered at village/urban-block level.
- ▶ Endogeneity concerns with OLS; follow Duflo and Saez (2002) and Case and Katz (1991) in using an instrumental variable.

Baseline Empirical Estimation: Results

Table 2: Baseline IV-2SLS (Second-Stage) Estimation Results

Round	43			55			61			66		
Year	1987-88			1999-00			2004-05			2009-10		
Dep. Variable: Whether LPG is the Primary Cooking Fuel	Overall	Urban	Rural	Overall	Urban	Rural	Overall	Urban	Rural	Overall	Urban	Rural
Avg. Village/Urban block LPG Use Rate (except household i)	1.748*** (0.140)	1.979*** (0.152)	0.2 (1.310)	1.080*** (0.158)	1.240*** (0.186)	-0.050 (0.678)	0.801*** (0.270)	1.090*** (0.300)	1.553*** (0.678)	-0.472 (0.435)	-0.122 (0.615)	1.138** (0.640)
Observations	104148	39461	40794	102994	41897	60516	97933	34931	60775	67372	27383	38668

Notes: Values reported are marginal effects. Proportion of population in the same village or urban block in the highest income decile is used as an instrument. All specifications include controls for religion, social group and district. Standard errors are reported in the village/urban block level (reported in parentheses). *** and ** respectively denote significance at 0.01, 0.05 and 0% levels. Coefficient of constant has not been reported.

Comparison of Magnitude of Peer-Effects in LPG-Intensive States and Other States

Are peer-effects stronger in states which have higher rates of LPG adoption?

Table 3: Comparison of IV-2SLS (Second-Stage) Results in LPG-Intensive States and in Other States

Round	43			55			61			66		
Year	1987-88			1999-00			2004-05			2009-10		
Dep. Variable: Whether LPG is the Primary Cooking Fuel	Overall	Urban	Rural	Overall	Urban	Rural	Overall	Urban	Rural	Overall	Urban	Rural
Avg. Village/Urban block LPG Use Rate (LPG-Intensive States)	2.027*** (0.182)	2.426*** (0.191)	1.639** (0.914)	1.922*** (0.199)	2.086*** (0.219)	-0.556 (0.855)	1.049*** (0.375)	1.507*** (0.417)	0.02 (0.922)	0.249 (0.967)	0.6 (1.254)	2.213* (1.367)
Observations	32735	15228	14685	29596	14905	14611	26066	11798	14167	17602	8447	9105
Avg. Village/Urban block LPG Use Rate (Other States)	1.482*** (0.218)	1.726*** (0.236)	-2.346 (3.710)	0.615*** (0.245)	0.658*** (0.285)	0.049 (0.864)	0.607 (0.383)	0.735* (0.453)	1.922 (0.558)	-0.347 (0.504)	0.024 (0.766)	0.761 (0.693)
Observations	71414	24289	23475	73398	26987	45814	71851	23126	46633	49762	18936	29475

Notes: Coefficients on controls and constant have not been reproduced. Values reported are marginal effects. Proportion of population in the same village or urban block in the highest income decile is used as an instrument. All specifications include controls for religion, social group and district. Standard errors are clustered at the village/urban block level (reported in parentheses). *, ** and *** respectively denote significance at 10%, 5% and 1% levels.

Baseline Empirical Estimation Using Panel (IHDS) Data

Baseline Instrumental Variable Two-Stage Least Squares (IV-2SLS) Estimation:

$$A_{it} = \alpha_0 + \alpha_1 A_{-ijt} + \alpha_2 X_{it} + \mu_{it} \quad (3)$$

- ▶ A_{it} is the 0/1 dependent variable (does household i spend on LPG in year t ?), A_{-ijt} is the average rate of LPG adoption amongst all households in the same village/urban block as household i in year t (excluding household i), and α_1 is the coefficient of interest.
- ▶ Specification include household and year FE

Fixed Effects Estimations using Panel Data

Table 4: Fixed Effects Estimations: IV-2SLS (Second-Stage) Results

Dep. Variable: Whether HH i spends on LPG in year t	(1)	(2)
Average Vill/UB level Use Rate	1.076*** (0.113)	0.656*** (0.054)
Whether HH had access to electricity	0.002 (0.011)	0.031*** (0.007)
Whether at least 1 HH in the same vill/UB had access to kerosene	-0.073 (0.049)	0.06 (0.039)
Size of household	0.0007 (0.002)	0.001 (0.002)
Years of education of most educated adult	0.002 (0.001)	0.002*** (0.001)
Whether HH has a non-biomass cookstove?	0.047*** (0.010)	0.058*** (0.009)
Hours of use of cookstove (per day)	-0.009*** (0.002)	-0.005*** (0.002)
Amount of time spent collecting fuel (Hrs per day)	-0.0001 (0.0001)	-0.00004 (0.00006)
Whether HH has a vent in the kitchen	0.015*** (0.006)	0.011** (0.006)
Obs	9350	9350
Cragg-Donald Wald F statistic	29.146	375.805
Kleibergen-Paap rk Wald F statistic	51.69	51.555
P-Value	0	0
Instrument	Proportion of population in highest income decile	Average(village or urban block) income

Notes: Household and year fixed effects included in estimations. All specifications include controls for religion, social group and income (not reproduced). Robust standard errors are reported. *,** and *** respectively denote significance at 10%, 5% and 1% levels.

Comparison of Magnitude of Peer-Effects for LPG-Intensive States and Other States

Table 5: Fixed Effects Estimations: IV-2SLS (Second-Stage) Results

Dep. Variable: Whether HH <i>i</i> spends on LPG in year <i>t</i>	Overall	LPG-Intensive States	Other States
Average Village level Use Rate	1.076*** (0.113)	1.133*** (0.054)	0.996*** (0.043)
Whether HH had access to electricity	0.002 (0.011)	0.007 (0.021)	0.012 (0.015)
Whether at least 1 HH in the same village had access to kerosene	-0.073 (0.049)	-0.036 (0.035)	-0.054 (0.036)
Size of household	0.0007 (0.002)	0.007 (0.004)	-0.004 (0.004)
Years of education of most educated adult	0.002 (0.001)	0.002 (0.002)	0.002 (0.001)
Whether HH has a non-biomass cookstove?	0.047*** (0.010)	0.050** (0.027)	0.051*** (0.017)
Hours of use of cookstove (per day)	-0.009*** (0.002)	-0.004 (0.004)	-0.010*** (0.003)
Amount of time spent collecting fuel (per day)	-0.0001 (0.0001)	-0.0005*** (0.0002)	6.93 (8.51)
Whether HH has a vent in the kitchen	0.015*** (0.006)	0.020** (0.011)	0.012 (0.008)
Obs	9350	3318	6032
Cragg-Donald Wald F statistic	29.146	51.976	40.998
Kleibergen-Paap rk Wald F statistic	51.69	59.487	57.7
P-Value	0	0	0

Notes: Household and year fixed effects included in estimations. All specifications include controls for religion, social group and income (not reproduced). Robust standard errors are reported. Instrument is the proportion of sample (by village/urban block) which has an annual income in the highest (country-wide) income decile.

Policy Implications and Conclusion

- ▶ This paper attempts to inform about the role of informational spillovers in the diffusion process for clean energy in developing countries
- ▶ A household's decision to use LPG as the primary cooking fuel may depend on other households' (located in the same village, or urban block) decisions to do so, controlling for factors found to be important in the literature
 - ▶ Magnitude of peer-effects vary for rural and urban households
 - ▶ Peer- effects stronger amongst households residing in states which were favored in terms of supply and subsidies
- ▶ Policy implications: targeted subsidies, demonstration projects and informational campaigns

Thank you for your attention.