

Adding Fuel to Fire? Social Spillovers and Spatial Disparities in the Adoption of LPG in India

Suchita Srinivasan¹ Stefano Carattini²

¹Graduate Institute of International and Development Studies, Geneva, Switzerland

²School of Forestry & Environmental Studies, Yale University and Grantham Research Institute on Climate Change and the Environment

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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 negative health consequences in developing countries (WHO, 2016).
 - ▶ Global Burden of Disease (2013) report: 2.9 million deaths caused by ambient air pollution due to PM 2.5 in 2013.
 - ▶ Estimates suggest that cooking with traditional biomass accounts for almost 18% of greenhouse gas emissions (Bond et al. (2007)).
- ▶ Cleaner alternatives are available (Liquefied Petroleum Gas, or LPG), but they are more expensive, and their use is restricted to urban areas.

Background on Cooking Fuel Use in India

- ▶ Focus of this paper is on LPG.
 - ▶ LPG is the cheapest "clean" cooking fuel available, but it still remains unaffordable to many, 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.
- ▶ Fuel choice varies between rural and urban households.
 - ▶ Urban households use electricity, LPG or kerosene as sources of cooking fuel.
 - ▶ Rural households have strong preferences for biofuels such as firewood, charcoal and agricultural waste.

Distribution of Households by Primary Cooking Fuel Type

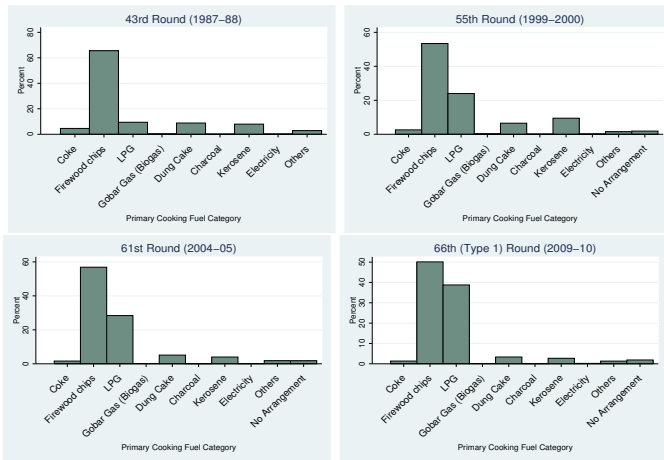


Figure 1: Source: National Sample Survey (GoI)

Evolution of the Population Share (%) Using LPG as the Primary Cooking Fuel: 1983 to 2012

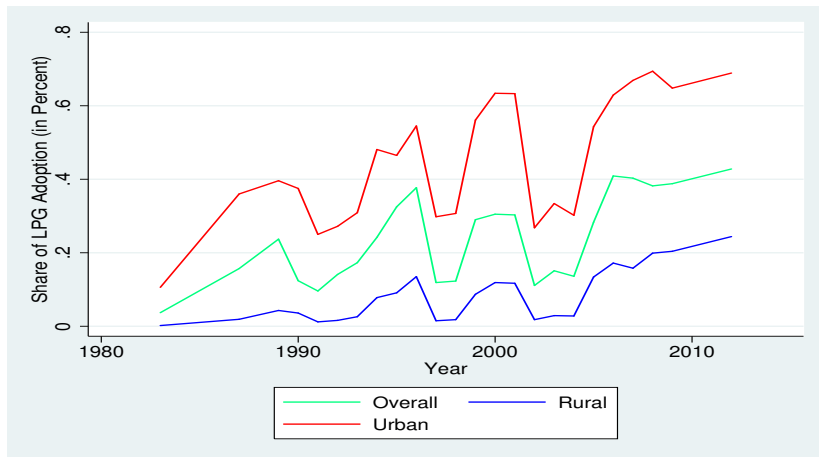
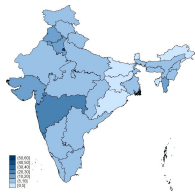
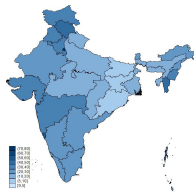


Figure 2: Source: National Sample Survey (GoI)

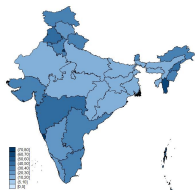
Proportion of Population Using LPG as the Primary Cooking Fuel (By State)



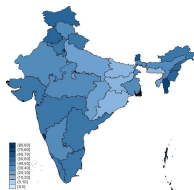
(a) 1987-88



(b) 1999-2000



(c) 2004-05



(d) 2009-10

Figure 3: Source: National Sample Survey (GoI)

Literature Review

Ample Literature exists on the use of clean cookstoves and clean cooking fuels in developing countries.

- ▶ Role of socio-economic factors in their adoption (Hanna, Duflo and Greenstone (2016), Lewis and Pattanayak (2012), Farsi et. al. (2007), Gupta and Kohlin (2006)).
- ▶ Importance of regular use and maintenance of cookstoves (Hanna, Duflo and Greenstone (2016), Mobarak et al. 2012).

Relatively new strand of research focuses on the role of social interactions in the adoption of clean technologies.

- ▶ Evidence on solar PV cells (Bollinger and Gillingham (2012), Graziano and Gillingham (2014)).
- ▶ Developing country evidence focuses on agricultural practices (Bandiera and Rosul (2006), Munshi (2004)).

Objective and Main Findings

▶ Objective

- ▶ To investigate whether social spillovers exist in the adoption of LPG in India.
- ▶ How do these effects vary across different subgroups of the population?
- ▶ Do they exacerbate/ameliorate existing spatial disparities?

▶ Main Results

- ▶ We find that a household is more likely to adopt LPG if other households residing in the same village/urban block do so.
- ▶ These effects are more persistent amongst rural households than urban households.
- ▶ These effects are weaker in states with high prior rates of LPG adoption.
- ▶ Social spillovers may be stronger for households that belong to certain social networks (such as caste associations).

Description of Data

- ▶ Data: National Sample Survey on Household Consumer Expenditure (Ministry of Statistics and Programme Implementation, GoI).
 - ▶ 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)).
- ▶ India Human Development Survey Data (University of Maryland and National Council of Applied Economic Research, India).
 - ▶ Two rounds of IHDS panel data (2005-06 and 2011-12)
- ▶ Households asked detailed questions about their expenditure on items over a "reference period".
- ▶ Geographical information includes the district and state of residence.
- ▶ It is possible to identify households that live in the same village/urban block.

Baseline Empirical Estimation Using Cross-Sectional (NSS) Data- Model

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

- ▶ A_i is a binary variable indicating whether LPG is the primary cooking fuel of household i .
- ▶ A_{-ij} is the average LPG adoption rate amongst all households (other than household i) in village/urban block j .
- ▶ X_i denote household-specific controls, such as household size, age, gender and level of education of the head of the household, whether the household has access to electricity, firewood, prices of LPG and kerosene, and whether the household resides in a district which is adjoining a large urban centre.
- ▶ μ_i is a household-specific error term.

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

$$A_i = \alpha_0 + \alpha_1 A_{-ij} + \alpha_2 X_i + \mu_i$$

- ▶ Endogeneity concerns with estimation using OLS (Manski (1993), Manski (2000), Moffitt et al. (2001)).
- ▶ Instrumental Variable Two-Stage Least Squares (IV-2SLS) estimation.
- ▶ Instrument A_{-ij} with proportion of population of each village/urban block belonging to the highest income decile (Duflo and Saez (2002), Case and Katz (1991)).
- ▶ Dummies for MPCE, religion, social group and district included. Standard errors clustered at the village/urban block level.

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

Table 1: NSS Data Linear Probability Model (LPM) and Instrumental Variable Probit Model (IVM) Results

Round	43		55		61		66	
Year	1987-88		1999-00		2004-05		2009-10	
Dep.Var.: Whether prim. cooking fuel of HH <i>i</i> is LPG	LPM	IVM	LPM	IVM	LPM	IVM	LPM	IVM
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Average LPG use rate (Village/ Urban Block)	0.619*** (0.007)	1.748*** (0.140)	0.468*** (0.007)	1.080*** (0.158)	0.353*** (0.007)	0.801*** (0.270)	0.341*** (0.007)	-0.472 (0.435)
Whether bordering an urban centre?	-0.053*** (0.013)	0.085 (0.159)	-0.051 (0.065)	-0.038** (0.021)	-0.131*** (0.060)	-0.259 (0.194)	-0.025 (0.045)	-0.043 (0.278)
Whether HH has access to electricity?	0.037*** (0.002)	0.635*** (0.029)	0.040*** (0.003)	0.703*** (0.024)	0.035*** (0.003)	0.657*** (0.028)	0.037*** (0.004)	0.636*** (0.036)
Whether HH lives in a rural area?	0.011*** (0.002)	-0.483*** (0.034)	-0.007 (0.003)	-0.249*** (0.045)	-0.011*** (0.003)	-0.323*** (0.075)	-0.001 (0.004)	-0.647*** (0.111)
Whether HH purchased a cookstove in last 30/365 days?	-0.033*** (0.006)	-0.169*** (0.035)	-0.107*** (0.005)	-0.415*** (0.026)	-0.021 (0.022)	-0.066 (0.116)	0.006 (0.017)	0.088 (0.097)
Household size	0.009*** (0.0003)	0.128*** (0.004)	0.017*** (0.0005)	0.119*** (0.003)	0.015*** (0.0005)	0.102*** (0.003)	0.019*** (0.0006)	0.107*** (0.006)
Age of head of household	0.001*** (0.00007)	0.018*** (0.001)	0.001*** (0.00009)	0.009*** (0.0006)	0.0008*** (0.0001)	0.006*** (0.001)	0.0008*** (0.0001)	0.005*** (0.0008)
Whether head of HH is female	0.006*** (0.002)	0.157*** (0.034)	0.021*** (0.003)	0.187*** (0.023)	0.013*** (0.003)	0.142*** (0.021)	0.011*** (0.004)	0.126*** (0.023)
Whether head of HH is educated	0.041*** (0.002)	0.732*** (0.027)	0.089*** (0.002)	0.638*** (0.017)	0.083*** (0.002)	0.623*** (0.002)	0.100*** (0.003)	0.564*** (0.021)
Price of LPG	-0.00003 (0.0005)	0.0004 (0.002)	-0.010*** (0.002)	-0.042*** (0.006)	-0.0004** (0.0002)	-0.007*** (0.002)	-0.004*** (0.001)	-0.019*** (0.005)
Price of Kerosene	0.004*** (0.001)	-0.009 (0.018)	0.00004 (0.00009)	-0.0007 (0.002)	-0.00001** (0.000006)	-5.26 (4.17)	-0.003 (0.002)	-0.005 (0.010)
Whether HH has access to firewood	-0.134*** (0.003)	-1.147*** (0.029)	-0.229*** (0.004)	-1.084*** (0.022)	-0.396*** (0.005)	-1.600*** (0.030)	-0.435*** (0.006)	-1.874*** (0.025)
Observations	104845	104148	102994	102994	97963	97933	67374	67372
R ²	0.4729		0.5775		0.6004		0.6381	
Wald test of endogeneity (<i>Chi</i> ²)		0.21		31.64		10.47		21.28
<i>P</i> -value		0.6438		0		0.0012		0

Baseline Empirical Estimation Using Panel (IHDS) Data-Model I

$$A_{it} = \alpha_0 + \alpha_1 \delta_i + \alpha_2 A_{-ijt} + \alpha_3 X_{it} + \alpha_4 \tau_t + \mu_{it} \quad (2)$$

- ▶ A_{it} is a binary variable indicating whether household i spent on LPG in the last 30 days prior to the date of the survey (as of time period t).
- ▶ A_{-ijt} is the average LPG adoption rate amongst all households (other than household i) in village/urban block j in time period t .
- ▶ Dummies for income, religion, and social group included. Standard errors clustered at the village/urban block level.
- ▶ X_i denote household-specific controls.
- ▶ δ_i is a household-specific fixed effect, τ_t is a time effect.
- ▶ IV-2SLS estimation methodology used (as with NSS data).

Baseline Empirical Estimation Using Panel (IHDS) Data-Model II

$$A_{it} = \alpha_0 + \alpha_1 \delta_i + \alpha_2 A_{-ijt} + \alpha_3 X_{it} + \alpha_4 \tau_t + \mu_{it}$$

- ▶ We test for the S-shaped diffusion curve of LPG across Indian states. Using the 61st round of the NSS data (from 2004-05), we create dummies for states with adoption rates: below 20%, between 20-30%, between 30-40% and more than 40%. These are interacted with the observed level of adoption in the village or urban block, to analyse how the spillovers change across the different states, and over time.
- ▶ We also estimate this model for different social networks/ subgroups within the population.
- ▶ Linear probability model used for both estimations

Baseline Empirical Estimation Using Panel (IHDS) Data: Results

Table 2: IHDS Data Baseline Results

Dependent Variable: Whether HH <i>i</i> spent on LPG in the last 30 days Column	LPM (1)	IV-2SLS (Overall) 2nd-Stage (2)	LPM (Using 2004-05 NSS LPG Adoption Rates) (3)
Average LPG use rate (Village/ Urban Block)	1.009*** (0.006)	1.157*** (0.032)	
Avg. LPG Use Rate * Indicator for 1999-2000 LPG adoption rate less than 20%			0.95*** (0.013)
Avg. LPG Use Rate * Indicator for 1999-2000 LPG adoption rate between 20-30%			1.00*** (0.012)
Avg. LPG Use Rate * Indicator for 1999-2000 LPG adoption rate between 30-40%			0.984 (0.017)
Avg. LPG Use Rate * Indicator for 1999-2000 LPG adoption greater than 40%			-0.720 (1.247)
Whether HH lives in a rural area?	-0.089 (0.062)	-0.109** (0.060)	-0.050 (0.061)
Whether HH has access to electricity?	0.032*** (0.008)	-0.028** (0.017)	0.048*** (0.015)
Household size	-0.002 (0.002)	0.007*** (0.003)	-0.005** (0.003)
Number of years of education of household head	0.004*** (0.001)	-0.00007 (0.001)	0.003*** (0.001)
Whether household has non-biomass cookstove?	0.074*** (0.011)	0.016 (0.016)	0.075*** (0.012)
Hours of cookstove use (/ Day)	-0.011*** (0.003)	-0.007*** (0.003)	-0.011*** (0.003)
Time spent in collecting firewood (/ Trip)	0.00004 (0.00007)	-0.0002*** (0.0001)	0.00001 (0.00009)
Whether household has vent in kitchen?	0.0134** (0.007)	0.018*** (0.008)	0.013* (0.008)
Observations	18590	9350	17072
Hansen J-statistic		7.93	
P-value		0.1601	

Estimation of Spillovers in Social Networks: Panel (IHDS) Data

Table 3: IHDS Data Social Network (LPM) Results

Dependent Variable: Whether HH <i>i</i> spent on LPG in last 30 days Column	Women's Group (1)	Self-Help Group (2)	Credit/Savings Organisation (3)	Religious/Social Organisation (4)	Caste Association (5)
Average LPG use rate (Village/ Urban Block)	1.004*** (0.047)	1.005*** (0.030)	0.867*** (0.053)	0.934*** (0.059)	1.066** (0.059)
Whether HH has access to electricity?	-0.196 (0.146)	-0.029 (0.038)	0.183** (0.092)	0.194** (0.109)	0.176 (0.171)
Household size	0.0004 (0.011)	-0.003 (0.007)	0.001 (0.010)	-0.013** (0.007)	-0.0006 (0.014)
Number of years of education of household head	0.0004 (0.007)	-0.007 (0.004)	0.01 (0.008)	-0.003 (0.007)	0.006 (0.006)
Whether household has non-biomass cookstove?	0.100* (0.060)	0.083 (0.053)	0.154*** (0.053)	0.112* (0.063)	0.077 (0.080)
Hours of cookstove use (/ Day)	-0.016* (0.010)	-0.002 (0.010)	-0.035*** (0.010)	-0.004 (0.011)	-0.011 (0.013)
Time spent in collecting firewood (/ Trip)	-0.00002 (0.0004)	-0.00007 (0.0004)	0.0006 (0.0006)	-0.0002 (0.0003)	-0.00002 (0.0006)
Whether household has vent in kitchen?	0.090* (0.048)	0.052 (0.034)	0.034 (0.037)	-0.066 (0.044)	-0.107* (0.060)
Observations	1576	2278	1727	2460	1920
R ² (Overall)	0.6324	0.7252	0.5536	0.6092	0.6199

Estimations for Rural/Urban Sub-populations

Table 4: NSS and IHDS Results on Rural and Urban Households

Data Year Round Dep.Var.: Whether HH uses LPG Column	NSS								IHDS	
	1987-88 43		1999-00 55		2004-05 61		2009-10 66		2005-06 and 2011-12 Panel Data	
	Rural (1)	Urban (2)	Rural (3)	Urban (4)	Rural (5)	Urban (6)	Rural (7)	Urban (8)	Rural (9)	Urban (10)
Average LPG use rate (Village/ Urban Block)	0.425*** (0.031)	0.506*** (0.009)	0.538*** (0.013)	0.431*** (0.009)	0.368*** (0.011)	0.270*** (0.011)	0.400*** (0.011)	0.239*** (0.011)	1.006*** (0.017)	1.00*** (0.094)
Average LPG use rate * 2011 indicator									-0.057*** (0.030)	0.058 (0.134)
Whether bordering an urban centre?	-0.038 (110.147)	-0.006 (0.024)	-0.002 (0.002)	-0.023*** (0.006)	-0.138 (0.100)	-0.054 (0.053)	-0.045 (0.074)	-0.169 (0.146)		
Whether HH has access to electricity?	0.018*** (0.0014)	0.053*** (0.004)	0.031*** (0.002)	0.088*** (0.006)	0.029*** (0.003)	0.076*** (0.007)	0.022*** (0.004)	0.097*** (0.010)	0.028** (0.014)	0.171* (0.103)
Whether HH purchased a cookstove in last 30/365 days?	0.007 (0.007)	-0.058*** (0.007)	-0.034*** (0.005)	-0.135*** (0.007)	0.003 (0.027)	-0.046 (0.036)	0.001 (0.020)	0.016 (0.029)		
Household size	0.001*** (0.0002)	0.028*** (0.0009)	0.006*** (0.0004)	0.039*** (0.001)	0.009*** (0.0005)	0.030*** (0.001)	0.015*** (0.0007)	0.027*** (0.001)	-0.005* (0.003)	-0.010 (0.011)
Age of head of household	0.0001*** (0.00004)	0.004*** (0.0002)	0.0004*** (0.00008)	0.002*** (0.0002)	0.0004*** (0.0001)	0.001*** (0.0002)	0.0008*** (0.0002)	0.001*** (0.0002)		
Whether head of HH is female	0.007 (0.001)	0.014*** (0.006)	0.009*** (0.003)	0.040*** (0.006)	0.005 (0.003)	0.029*** (0.006)	0.005 (0.005)	0.026*** (0.006)		
Whether head of HH is educated	0.013*** (0.001)	0.088*** (0.004)	0.057*** (0.002)	0.138*** (0.005)	0.066*** (0.003)	0.121*** (0.005)	0.093*** (0.004)	0.116*** (0.006)		
Price of LPG	-0.0002 (0.002)	0.00001 (0.0005)	-0.001** (0.0007)	-0.0126*** (0.002)	-0.0002*** (0.00008)	-0.002** (0.0009)	-0.00003 (0.002)	-0.007*** (0.001)		
Price of kerosene	0.002* (0.001)	0.012*** (0.003)	0.00003 (0.00008)	-0.0004 (0.0005)	-0.000005 (0.00001)	-0.00001 (0.000004)	0.002 (0.002)	0.003 (0.004)		
Whether HH has access to firewood	-0.050*** (0.004)	-0.194*** (0.005)	-0.162*** (0.006)	-0.248*** (0.006)	-0.372*** (0.0072)	-0.413*** (0.007)	-0.440*** (0.008)	-0.435*** (0.008)		
Number of years of education of household head									0.003*** (0.001)	0.006 (0.007)
Whether household has non-biomass cookstove?									0.061*** (0.012)	0.196*** (0.050)
Hours of cookstove use (/ Day)									-0.012*** (0.003)	-0.020 (0.014)
Time spent in collecting firewood (/ Trip)									-0.00002 (0.00008)	0.001*** (0.0006)
Whether household has vent in kitchen?									0.001 (0.008)	0.080* (0.049)
Time trend									0.031** (0.017)	-0.020 (0.116)
Observations	65307	39567	61097	41897	62937	35026	39915	27459	13730	3342

Policy Implications and Conclusion

- ▶ Evidence on positive social spillovers in the decision to use LPG between households residing in the same village or urban block.
- ▶ These spillovers appear to vary in strength across different sub-groups of the population.
 - ▶ Evidence of social spillovers amongst both rural and urban households, which weaken over time.
 - ▶ Sharper weakening for urban households, while rural households experience a prolonged duration of positive spillover effects.
 - ▶ Social spillovers are weaker for households in states with higher (initial) LPG adoption rates (in line with the S-shaped diffusion model of technology).
 - ▶ Evidence suggests that social spillovers stronger amongst households that belong to a social network (such as caste associations).
- ▶ Policy implications: targeted subsidies, demonstration projects and informational campaigns.

Thank you for your attention.