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Access to modern fuels and satisfaction with cooking arrangements: Survey evidence from rural India☆

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ABSTRACT

Subjective satisfaction is a central element of technology adoption, but scholars have not analyzed the determinants of households' satisfaction with their cooking arrangements. Drawing on an original survey of 8568 households across six Indian states, we uncover the predictors of such satisfaction. Households do not find firewood collection inconvenient, but they are dissatisfied if they have to travel long distance to purchase firewood. Among sub-components of subjective satisfaction, reduction in smoke, speed of cooking, and quality of meals dominate over others (difficulty, cost, and safety). Moreover, we identify access to LPG – a modern cooking fuel – as a strong and robust predictor of high subjective satisfaction, mostly through reduction in smoke and increase in speed of cooking. Rural households ascribe a lot of value to access modern cooking fuels that reduce indoor air pollution, and beneficiaries of interventions to improve such access would value it. Thus, efforts to reduce reliance on cooking with traditional biomass are not just paternalistic top-down interventions but contribute to significantly improve households' satisfaction with their cooking arrangements.

Introduction

The lack of access to modern cooking fuels is a major obstacle to socio-economic development (Masera et al., 2000; Mobarak et al., 2012; Bansal et al., 2013; Yadama, 2013; Cheng and Urpelainen, 2014). According to the International Energy Agency (2015), 2.7 billion people in the world continue to rely on traditional biomass for their cooking needs. The costs of traditional biomass are both economic and health-related. Women and children in developing countries spend a lot of time collecting firewood, with a high opportunity cost from forgone earning opportunities (Heltberg, 2004). Indoor air pollution from traditional biomass also causes 3.8 million premature deaths every year.[1] As Meera Subramanian put it in a recent *Nature* commentary, the "deadly dinners" cooked with traditional biomass cookstoves take a "terrible toll" (Subramanian, 2014). According to Parikh et al. (2001), housing in rural India is such that not only is the main cook vulnerable to indoor air pollution while cooking with biomass, but the rest of the family also suffers from a "passive cooking effect".

For the 2.7 billion people who continue to rely on traditional biomass, a key issue is their subjective satisfaction with their current cooking arrangement. Indeed, regardless of the social cost of the continued use of traditional biomass cookstoves, people base their cooking technology choices on their own experience. If households consider their traditional cooking arrangement satisfactory, they have little incentive to make investments in modern alternatives. In this context, how can social scientists and rural energy researchers evaluate and assess the determinants of subjective satisfaction with cooking arrangements?

As shown in Lewis and Pattanayak's (2012) meta-analysis, most studies on the determinants of the adoption of improved fuels and cookstoves examine demographics, income or geographic variables, while ignoring subjective components of satisfaction. For instance, Pandey and Chaubal (2011) highlight the role of education and income in the adoption of clean fuels for cooking in rural India. Some studies go further and include product-related characteristics such as reduction in smoke, speed of cooking, ease of use, and taste of the food in their assessment of the factors of LPG adoption (Budya and Arofat, 2011; Terrado, 2005). However, to our knowledge, none of them offers a framework to study the determinants of satisfaction

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[1] See http://www.who.int/mediacentre/factsheets/fs292/en/ (accessed February 18, 2016).

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0973-0826/

with cooking arrangements. We propose a new analytical approach to explain variations in subjective satisfaction with cooking activities and focus on rural households that rely on traditional biomass. We conceptualize rural households' subjective satisfaction as depending on four dimensions of the cooking experience: convenience, cost, access to alternatives, and perceptions of different dimensions of cooking activities. Using original data from the world's largest energy access survey to date (8568 rural households in six major states of rural India), we then estimate regression models to see how overall satisfaction with one's cooking arrangement depends on these different dimensions. We estimate these models separately for the full sample, for households that use firewood, and for households that regularly collect their own firewood.

The analysis shows that access to modern fuels has a strong positive association with subjective satisfaction. When households with and without LPG are compared, the predicted difference in satisfaction is strongly in favor of those with LPG at home. It accounts for approximately 73% of a standard deviation of our dependent variable, and the result is robust to focusing only on households that use and/or collect firewood. Households with LPG also consider it a much higher policy priority for the government, suggesting that access to modern cooking fuels is something that rural households value greatly. Another notable finding is that while households do *not* seem to find firewood collection inconvenient, their subjective satisfaction does decrease if they have to purchase firewood from markets. The coefficient is much smaller than that for LPG, however. The fact that collection does not seem to be a source of dissatisfaction is in agreement with Masera et al.'s (2000) criticism of the "energy ladder" model. As they claim, cooking practices and cultural preferences play a crucial role in the choice of cooking fuel. When we focus on households that do collect firewood regularly, the dissatisfaction caused by purchases is more related to distance to the nearest firewood market than to the price of firewood. A possible explanation is that regular collectors adapt their collection pattern to market prices. Although they do not study satisfaction with cooking arrangements but the adoption of modern fuels, Das and Srinivasan (2012) also find a negative correlation between distance to market for modern fuel and their adoption rate. It is in agreement with our finding that distance to market is an important source of dissatisfaction, which can in turn drive one's choice of cooking fuel.

These results are important both academically and for practitioners. Academically, our key contribution is to identify access to modern cooking fuels and distance to firewood markets as factors predicting subjective satisfaction. Our results from a large original survey show that improving access to LPG can greatly increase subjective well-being in rural households through reduction in indoor pollution and increase in speed of cooking. Our findings also suggest that some sub-components of subjective satisfaction such as reduction in smoke, speed of cooking, and quality of meals are more correlated to overall satisfaction than difficulty, cost, and safety of the cooking arrangements. Practitioners, in turn, can learn from this result that households ascribe a lot of value to modern cooking fuels. Going further, problems associated with selling technologies such as efficient cookstoves probably reflect issues with their design, efficiency or price.

Modern cooking fuels: access and satisfaction

While the importance of access to modern cooking fuels is by now acknowledged and understood, scholars have made much less progress in understanding how households in developing countries assess the costs and benefits of access to modern cooking fuels. Most of the relevant studies such as Takama et al. (2012) focus on willingness to pay for alternatives, such as LPG and efficient cookstoves. Results from these studies suggest that preferences for traditional solutions, affordability, liquidity constraints and asymmetric information are all major obstacles to higher sales (Levine et al., 2012; Mobarak et al., 2012; Cheng and Urpelainen, 2014; Sehjpal et al., 2014).

However, these studies do not specifically address the question of subjective perceptions. Willingness to pay does not always amount to profound dissatisfaction with one's cooking arrangement. It may instead reflect disposable income (Masera et al., 2000; Cheng and Urpelainen, 2014) or interest in exploring new technologies (Dercon and Christiaensen, 2011). An analytical framework for household demand for modern cooking fuels would have to account for the household members' subjective satisfaction with the conventional alternative. In the absence of subjective dissatisfaction with traditional biomass and cooking methods, it is hard to see why households would spend their often scarce income on modern alternatives.

Our analysis of satisfaction with respect to cooking fuels draws on a broader literature on subjective well-being. A main contribution is Diener et al.'s (1985) satisfaction with life scale aiming at assessing people's satisfaction with their life as a whole. On the other hand, the "Scandinavian approach" of Erikson and Uusitalo (1986) is based on measuring indicators of various components of well-being. Many studies have followed this methodology, including Bookwalter and Dalenberg (2004) who conducted a survey in South Africa to assess subjective well-being of households based on various dimensions such as housing, sanitation, and transportation. We anchor our measure of satisfaction with cooking arrangements in this literature by combining the latter two schools of thought. On the one hand, we measure different components of satisfaction such as cost, access to modern fuel, and convenience. On the other hand, we also include indicators of the following subjective sub-components: satisfaction with smoke and cost, quality of meals, speed of cooking, and ease of use.

The World Bank's Global Tracking Framework (GTF) for the United Nations Sustainable Energy for All is one important effort to measure the quality of access to modern cooking technologies (SE4ALL, 2014). Under this framework, cookstoves are evaluated based on generation of indoor air pollution, convenience of fuel collection and use, and adequacy of the cooking solution for the household's needs. However, the GTF approach has important limitations. Most importantly, it automatically classifies any household with a traditional cookstove as having a low level of cooking energy access, regardless of the reported subjective level of satisfaction. As such, the GTF framework does not distinguish between varying levels of satisfaction among that vast majority of households that rely on traditional biomass for their daily cooking needs. We suggest here a more complete framework aimed at studying demand for cooking fuels.[2]

Although many frameworks to measure satisfaction with electricity have been suggested, rigorous approaches to measuring the quality of cooking arrangements remain scarce. Indeed, the contrast to the numerous approaches to measuring the quality of rural electricity access is striking. As an important component of demand, subjective satisfaction with the quality of electricity supply plays a major role in the literature on rural electrification (Parikh et al., 2012; Barnes, 2014; Dugoua and Urpelainen, 2014; Aklin et al., 2016b). While the role of subjective satisfaction has been largely neglected in the study of cooking arrangements, scholars have proposed analytical approaches and provided data on the determinants of satisfaction with domestic electricity supply. We believe that such

[2] In Practical Action's Total Energy Access (Practical Action, 2014, 48), the quality of cooking energy supply depends only on the stove and the fuel, and thus does not capture subjective perceptions.

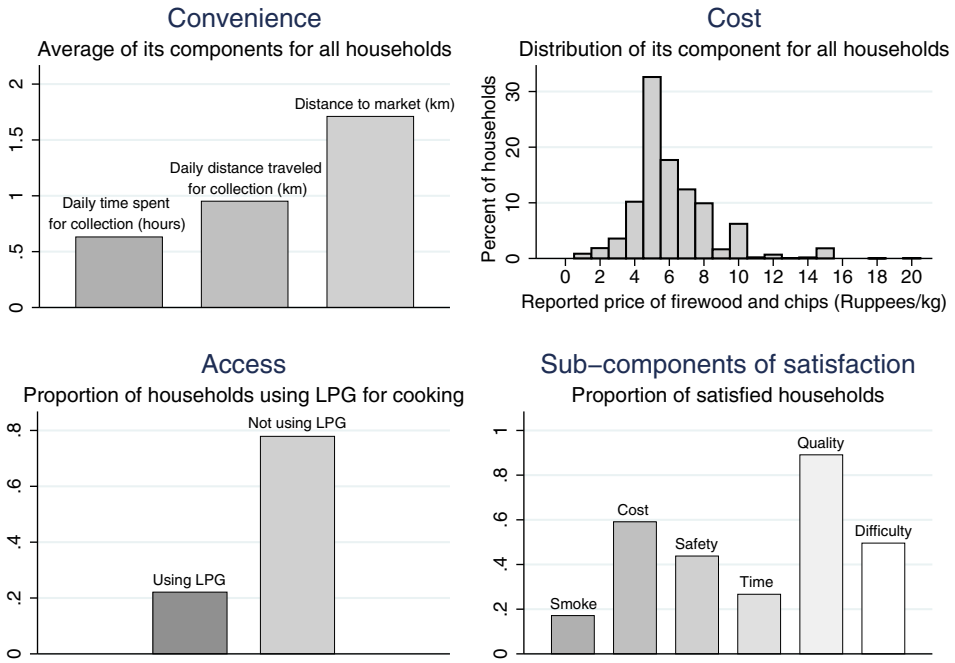

Fig. 1. The four dimensions of subjective satisfaction: convenience, cost, access, and sub-components of subjective satisfaction.

approaches are necessary for progress in the study of demand for modern cooking fuels in the developing world.

Determinants of subjective satisfaction

We propose a new analytical approach that emphasizes four dimensions of satisfaction with cooking arrangements: convenience, cost, access to alternatives, and sub-components of subjective satisfaction. To begin with, consider the *convenience* of firewood procurement and use in cooking. Because rural households procure firewood either by their own collection or from local markets, we propose that the convenience of firewood procurement depends on the time spent on these activities and the distance traveled for them. Empirically, we assess the time that households spend and the distance to collection or markets. Time spent is a measure of the opportunity cost of firewood collection; distance to collection site or markets is a measure of the difficulty of increasing firewood supply when needed. In practice, we pose these questions only to regular collectors of firewood. Hence, measures of the daily time and distance for collection are coded as zero for people collecting monthly or yearly.[3] For regular collectors in our Indian sample, the average daily time spent for collection is 1 h and 40 min and the average distance traveled for this purpose per day is 2.57 kilometers (km). Concerning distance to market, we extrapolated the values given by people in the same village to account for missing values. The average distance to market for all collectors is 1.80 km and it is 1.62 km for regular collectors.

The next consideration is *cost*. Because many households spend money to purchase firewood, we can investigate how the cost of procuring firewood from the markets shapes their subjective satisfaction. Using the survey data, we measure cost as the reported price (in rupees) of 1 kg of firewood. While affordability depends on households' specific needs, the unit cost of firewood is a simple, comparable, and relevant metric across all households in the sample. Even though this question was asked to all users of firewood and chips for cooking, we extrapolated the values reported by people in the same village to account for missing values. The average market price for firewood and chips reported by all collectors is 5.98 rupees per kilogram (r/kg). For comparison, it is equivalent to 0.09 USD given the exchange rate at the time of writing (July 2016). The average price reported by regular collectors is 5.73 r/kg.

Third, we examine the role of *access to modern cooking alternatives*. In practice, the only widespread alternative to firewood for cooking in India is an LPG connection, with 22% of households in our sample using it for cooking. Modern biomass-based cooking technologies, such as efficient cookstoves and biogas equipment, remain virtually non-existent in the sample. Here, we do not distinguish exclusive use of LPG from the "stacking" of firewood and LPG for simultaneous use (Cheng and Urpelainen, 2014) because our focus is on the ability to use a modern cooking fuel, instead of the preferred use thereof. Among LPG users, some households may choose to use LPG exclusively while others continue to stack both firewood and LPG. Empirically, we proxy for access to LPG with an indicator for any LPG use in the household, as we do not have data on whether households without LPG could easily begin using this fuel.

Finally, we consider *sub-components* of overall subjective satisfaction that correspond to perceptions of problems related to cooking activities. These sub-components are fundamentally different from the above determinants in that they are based on subjective perceptions of specific issues related to cooking. Specifically, we consider satisfaction with indoor smoke, cost, safety, time used, quality of food, and the difficulty/inconvenience of cooking.

Fig. 1 provides a graphical illustration of some descriptive statistics relevant to the dimensions of our approach. To begin with, the upper-left corner shows summary statistics for our empirical measures of convenience. Note that the units for the different components of convenience differ (hours and kilometers) and that higher indicators are related to a worsening of convenience given the variables we consider. The upper-right corner shows the distribution of firewood price (r/kg). The lower-left and lower-right panels,

[3] For robustness, we also run our regressions with a threshold model taking into account potential nonlinearity introduced by this coding. Results are available in Tables A31–A34.

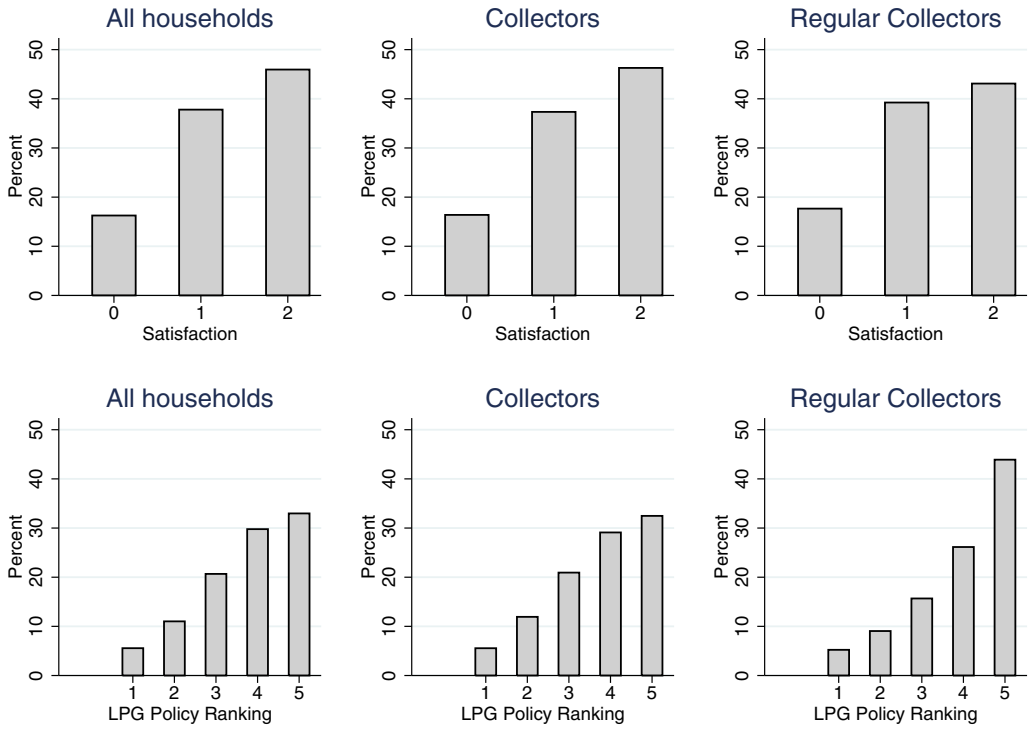

Fig. 2. Distribution of the dependent variables as percentage of respondents in three samples.

in turn, illustrate access to LPG and the sub-components of subjective satisfaction. Together, these dimensions provide a general, widely applicable framework for examining satisfaction with cooking arrangements. With relatively minor adjustments to the measurement strategy, this framework can be used to understand the subjective satisfaction of different kinds of rural households in different settings.

Results

We first present the results on subjective satisfaction, then investigate policy preferences, and summarize our robustness checks. The empirical analysis is based on responses from 8563 household heads in six states of India (Aklin et al., 2016b; Jain et al., 2015; Aklin et al., 2016b). The key dependent variables are subjective satisfaction with cooking arrangements (0–2 scale, with higher values indicating more satisfaction) and LPG as a policy priority (1–5 scale, with higher values indicating less priority). For further details, see Data and methods below.

Fig. 2 presents the distribution of the dependent variables for the following samples: all households, all households that collect firewood, and regular collectors — households that collect firewood at least weekly. We note that 46% of all households are satisfied with their cooking arrangement. Among them, 18% use only LPG for cooking, 19% both collect firewood and use LPG, and 49% collect firewood without using any LPG. Only 6% of all households rank LPG as a top priority, and among them 26% already use LPG for cooking.

Results on subjective satisfaction

We begin with a general comparison of subjective satisfaction with cooking arrangements across all households. When all households are included in the regression analysis, we can only conduct basic comparisons between different types of households. Indeed, a household that does not collect any firewood cannot be assigned a distance to the place of collection.[4] Thus, the explanatory variables are binary indicators (0/1) for whether a household collects firewood, purchases firewood, and uses LPG. In one model, we also add the subjective perceptions of sub-components of satisfaction describing cooking problems. With i denoting subjects, j denoting villages, and k denoting states, the linear regression equation can be written as follows:

$$\text{Satisfaction}_{ijk} = \alpha_k + \sum_c \beta_c x^c_{ijk} + \epsilon_{ijk} \quad (1)$$

where Satisfaction is the subject's reported satisfaction with their cooking arrangement (0–2), α_k is the state fixed effect, and x^c are covariates indexed by c. Finally, ϵ_{ijk} is an error term. Because we conduct survey analysis with subjects sampled by village, we cluster standard errors accordingly. Survey weights are applied throughout to ensure that the sample is representative of the population.

The results are shown in Table 1. In the first three models, indicators for firewood collection, marketplace purchases, and the use of LPG are included separately. Model 4 includes all of them, and Model 5 then adds the subjective perceptions of sub-components. Although our goal here is not to build a predictive model, the table reports the fit of each model (R^2). While not an obstacle to hypothesis testing, the generally low values suggest that much variation remains to be explained.

As the table shows, the two robust objective predictors of satisfaction with one's cooking arrangement are the need to purchase firewood (−) and use of LPG for cooking (+). In Model 4, where we do not control for subjective perceptions that are correlated to LPG for cooking, the coefficient on the latter variable is 0.54. Given that the standard deviation of the dependent variable satisfaction is 0.73,

[4] One could use the village-level mean as a proxy, but this measure could be biased if households choose not to collect exactly because they face unusually high distances relative to other villagers.

Table 1
General comparison of subjective satisfaction with cooking arrangements across all households in the sample. We estimate linear regressions, with higher values of the dependent variable indicating higher levels of satisfaction on a 0–2 scale.

	(1)	(2)	(3)	(4)	(5)
Firewood collection (=1)	−0.07***			−0.02	0.01
	(0.02)			(0.02)	(0.02)
Firewood purchase (=1)		−0.11***		−0.12***	−0.05**
		(0.02)		(0.02)	(0.02)
LPG for cooking (=1)			0.54***	0.54***	0.29***
			(0.02)	(0.02)	(0.02)
Satisfaction with smoke (=1)					0.16***
					(0.03)
Satisfaction with cost (=1)					0.12***
					(0.02)
Satisfaction with safety (=1)					0.14***
					(0.02)
Satisfaction with time consumption (=1)					0.21***
					(0.02)
Satisfaction with quality (=1)					0.25***
					(0.03)
Satisfaction with difficulty (=1)					0.16***
					(0.02)
Primary cook present (=1)	−0.07***	−0.06***	−0.05***	−0.05***	−0.05***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Constant	1.38***	1.36***	1.15***	1.20***	0.73***
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
State FE	Yes	Yes	Yes	Yes	Yes
Observations	8563	8563	8563	8563	8563
R^2	0.03	0.03	0.12	0.12	0.20

Standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

this estimate reflects a high positive correlation between the use of LPG and satisfaction with cooking arrangements. The coefficient on firewood purchase is −0.12 and translates a significant negative correlation between the purchase of firewood and satisfaction.

In Model 5, we also find that the coefficients on satisfaction with smoke, cost, safety, time consumption, quality, and difficulty are all significant at the 1% level of significance. Among the latter predictors of satisfaction with the cooking arrangement, the ones with the highest coefficients are quality and time consumption. Their respective coefficients are 0.25 and 0.21, or more than one-fourth of the standard deviation of satisfaction with cooking arrangements. This high coefficient on quality supports Heltberg's (2005) suggestion that alongside income, households may build their choice of cooking fuel on tastes and habits. It is notable that in Model 5, the coefficients for firewood purchase and LPG use remain in the same direction and statistically significant. This result confirms that although the subjective subcomponents are correlated to our measures of convenience and access, they are fundamentally different determinants of overall satisfaction.

To go further, let us now study the differences in coefficients between Model 4 and Model 5, the latter of which controls for subjective satisfaction measures. The difference in the coefficient on firewood purchase can be explained by the large negative correlation between this variable and the subjective measure of cost satisfaction (−0.29) (Tables A5, A6, and A7). Similarly, the variation in the coefficient on LPG use for cooking between Models 4 and 5 is related to a strong positive correlation between LPG use for cooking and satisfaction with smoke (+0.61), with difficulty (+0.22), and with time consumption (+0.43) (Table A5).[5] Comparing these results with a regression using the same specification but without controlling for LPG use (Table A27) confirms these findings. In the latter regression, the main predictors of satisfaction are the subjective sub-components described above, which are all significant at the 1% level of significance. In particular, satisfaction with smoke has the highest coefficient (0.34) followed by quality (0.27) and time consumption (0.24). All of them decrease when we control for LPG use but the highest drop is for the coefficient on smoke satisfaction. It suggests that the main benefit of LPG use in terms of subjective satisfaction is the reduction in smoke. Hence, households value LPG because they avoid indoor air pollution, can cook more conveniently, and spend less time on cooking.

The high satisfaction prompted by LPG use in cooking comes from reduced smoke, ease of use, and the speed of cooking. However, Model 5 also states that independently of all these positive features, there is still an additional satisfaction in using LPG for cooking. In Table A8, we see that this effect remains unchanged when we add additional control variables, including yearly savings and a dummy for the owning of a bank account. Therefore, we may think of psychological explanations for this inner value of using LPG, such as the intrinsic value of access, social status, and sense of pride. Such an effect is also described by Masera et al. (2000) as they highlight that LPG stoves are a "status symbol" and that they might be perceived as a sign of wealth.

To go further with a quantitative assessment of our coefficients, we replace the linear regression with an ordered logistic regression. The odd ratios for the general comparison of subjective satisfaction with cooking arrangements across all households are given in Table 2. Directions, significance, and relative magnitudes of the coefficients are similar to the ones we obtained through the linear regression estimation. In Model 4, we find again that the two robust objective predictors of satisfaction with one's cooking arrangement are the need to purchase firewood and the use of LPG for cooking.[6] The odd ratio for LPG use is 5.52, meaning that the odds of being satisfied with one's cooking arrangement versus being neutral or

[5] In contrast, the correlations with quality (+0.09) and safety (−0.03) satisfaction are weak. Unsurprisingly, the correlation with cost satisfaction is negative (−0.08).

[6] Note that the parallel lines assumption is satisfied for this two variables (Table 3).

Table 2
General comparison of subjective cooking arrangements across all households with an ordered logit model displaying odd ratios.

	(1)	(2)	(3)	(4)	(5)
Firewood collection (=1)	0.81***			0.90*	0.96
	(0.04)			(0.05)	(0.06)
Firewood purchase (=1)		0.76***		0.71***	0.85**
		(0.04)		(0.04)	(0.06)
LPG for cooking (=1)			5.60***	5.52***	2.81***
			(0.37)	(0.37)	(0.24)
Satisfaction with smoke (=1)					1.93***
					(0.18)
Satisfaction with cost (=1)					1.44***
					(0.08)
Satisfaction with safety (=1)					1.56***
					(0.07)
Satisfaction with time consumption (=1)					1.96***
					(0.13)
Satisfaction with quality (=1)					1.84***
					(0.13)
Satisfaction with difficulty (=1)					1.57***
					(0.08)
Primary cook present (=1)	0.85***	0.87***	0.87***	0.89**	0.85***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
State FE	Yes	Yes	Yes	Yes	Yes
Observations	8563	8563	8563	8563	8563

Exponentiated coefficients; standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

unsatisfied are more than five times higher for those who use LPG for cooking. The odd ratio of firewood purchase is 0.71, so that the odds of being satisfied with one's coking arrangement versus being neutral or unsatisfied decrease with firewood purchase. The odd ratio of LPG use drops to 2.81 with the introduction of sub-components of satisfaction in Model 5, but it remains significant and above one. As explained above, this change between Models 4 and 5 is due to the high correlation between LPG use and the subjective measures of satisfaction, which are all significant and have odd ratios higher than one. For instance, the odds of being satisfied with one's cooking arrangement versus being neutral or unsatisfied are twice higher for those who are satisfied with time consumption.[7]

As some of the variables do not satisfy the parallel slopes assumption, we further estimate a generalized ordered logit model in Table 3.[8] These models show that most variables have similar impacts on the probability of being unsatisfied relative to the other categories (upper panel), as well as on the probability of being unsatisfied or neutral relative to being satisfied (lower panel). The only notable exception is firewood collection: it does increase the odds of not being satisfied, but it does not predict the odds of being dissatisfied in particular. This discrepancy can explain why firewood collection is not a robust predictor in the linear and ordinary logistic regressions. We find that all the subjective satisfaction variables have odd ratios higher than 1. As expected, being satisfied with one of these dimensions increases the odds of being in a higher overall satisfaction category though the magnitude of the increase differs depending on the comparison.

As we saw, the subjective subcomponents of satisfaction are crucial in the understanding of the overall satisfaction with cooking arrangements. By studying the correlation between these variables and LPG use, we go further in our understanding of the valuation of modern cooking fuels by households. In Table 4, we confirm this analysis by presenting linear probability models of the subjective components of satisfaction (satisfaction with smoke, cost, safety, time, quality, and difficulty) on the independent variables used in Model 4 of Table 1. Given this specification, the coefficients show the estimated association between the explanatory variable and the probability of being satisfied with the subjective component in focus. Unsurprisingly, the coefficients on LPG use for cooking are very similar to the correlation coefficients in Table A5. LPG use is significantly associated with satisfaction with smoke (0.58), time (0.48), and difficulty (0.26). The coefficient of LPG use in the regression of the satisfaction with quality is smaller (0.08), although it is still significant at the 1% level. Similarly, LPG use is negatively associated with the satisfaction with cost (−0.06) as expected. Interestingly, the latter coefficient is smaller than the one describing the association between firewood purchase and the probability of satisfaction with cost (−0.29) (Model 2 of Table 4). Firewood collection does not have a significant coefficient in the cost satisfaction regression, suggesting that the opportunity to collect firewood does not increase cost satisfaction, perhaps because households collecting firewood do so out of necessity.[9]

Table 4 highlights the dominance of LPG use over firewood collection in terms of satisfaction with cooking arrangements. Indeed, with satisfaction with smoke as a dependent variable (Model 1 of Table 4), all coefficients are significant at the 1% level of significance but the one on LPG use (0.58) largely exceeds the ones associated with firewood use which are negative. Applying the same reasoning, we find that not only is LPG use associated with positive satisfaction with smoke but it is also associated with gains in times along with higher quality and ease of use compared to firewood use. Moreover, the cost of LPG seems to be less of a burden than the cost of firewood, as we explained earlier, perhaps because LPG is typically used by wealthier households that can afford it. In the end, it is only on safety considerations that households seem to prefer firewood collection (0.05) to LPG use (−0.02). This finding suggests that public health campaigns are still needed to sensitize rural households to the well-documented dangers of firewood use.

[7] The variable "Satisfaction with time consumption" satisfies the parallel lines assumption (Table 3).
[8] Estimations of the generalized ordered logit model for all collectors and regular ones are in Section A4.4 of the Appendix.
[9] 1001 subjects both collect firewood and use LPG. Hence, the common support assumption required for this interpretation holds.

Table 3
General comparison of subjective cooking arrangements across all households with a generalized ordered logit model displaying odd ratios. Some of the parallel lines assumptions are relaxed and the partial proportional odds model that best fits the data is presented. The "Unsatisfied" section presents the odd ratios corresponding to the odds of being unsatisfied versus being neutral or satisfied. The "Neutral" section at the bottom displays the odd ratios corresponding to the odds of being unsatisfied or neutral versus being satisfied.

	(1)	(2)	(3)	(4)	(5)
Unsatisfied					
Firewood collection (=1)	1.02			1.07	1.06
	(0.07)			(0.09)	(0.09)
Firewood purchase (=1)		0.67***		0.72***	0.87**
		(0.05)		(0.04)	(0.06)
LPG for cooking (=1)			5.59***	5.46***	2.66***
			(0.36)	(0.36)	(0.21)
Satisfaction with smoke (=1)					3.13***
					(0.69)
Satisfaction with cost (=1)					1.93***
					(0.14)
Satisfaction with safety (=1)					2.12***
					(0.17)
Satisfaction with time consumption (=1)					2.11***
					(0.15)
Satisfaction with quality (=1)					1.61***
					(0.17)
Satisfaction with difficulty (=1)					2.44***
					(0.20)
Primary cook present (=1)	0.85***	0.87***	0.88***	0.89**	0.87***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Neutral					
Firewood collection (=1)	0.74***			0.83***	0.90
	(0.04)			(0.05)	(0.06)
Firewood purchase (=1)		0.81***		0.72***	0.87**
		(0.05)		(0.04)	(0.06)
LPG for cooking (=1)			5.59***	5.46***	2.66***
			(0.36)	(0.36)	(0.21)
Satisfaction with smoke (=1)					1.89***
					(0.19)
Satisfaction with cost (=1)					1.26***
					(0.07)
Satisfaction with safety (=1)					1.43***
					(0.08)
Satisfaction with time consumption (=1)					2.11***
					(0.15)
Satisfaction with quality (=1)					2.63***
					(0.26)
Satisfaction with difficulty (=1)					1.39***
					(0.08)
Primary cook present (=1)	0.85***	0.87***	0.88***	0.89**	0.87***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
State FE	Yes	Yes	Yes	Yes	Yes
Observations	8563	8563	8563	8563	8563

Exponentiated coefficients; standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

The corresponding results for estimating the linear regression with households that actually use firewood are described in Table 5. For this analysis, we only include households that report using some firewood for cooking; this sample excludes households that exclusively use LPG, coal, agricultural residue, or other alternatives. We can thus use more precise measures for various aspects of the problems associated with traditional biomass. We refine our characterization of firewood collection by including the daily time spent on this activity and the traveled distance per day for collection. We also refine our measurement of firewood purchases by considering both firewood price (r/kg) and distance to firewood market (km). Again, the objective predictors of satisfaction are related to firewood purchases and use of LPG. The coefficient related to LPG use is 0.50, which is very similar to the one we found when considering all households. Concerning firewood purchases, the coefficient on (standardized) firewood price is −0.03 and the one on (standardized) distance to firewood market is −0.04. Given the standardization, an increase in one standard deviation of one of them is correlated to a decrease of approximately 0.04, which represents only 5.5% of the standard deviation of the dependent variable. The coefficients for the subjective satisfaction measures remain largely unchanged compared to the ones we had when considering all households. Differences between Models 4 and 5 can be explained in the same way as well. Both the ordered logistic regression and the generalized ordered logit model confirm these comments (Tables A20 and A25). Directions, significance, and relative magnitudes of the coefficients are similar to the ones we obtained through the linear regression estimation. Note that most of the variables satisfy the parallel lines assumption and that the odd ratio for LPG use equals 4.45 in Model 4 and 2.55 in Model 5 (Table A25).[10]

Finally, the results for households that collect firewood regularly (daily or weekly) are shown in Table 6. Overall, these results emphasize the importance of access to modern alternatives and

[10] LPG use variable satisfies the parallel lines assumption.

Table 4
General comparison of subjective subcomponents of satisfaction with cooking arrangements across all households in the sample. Subcomponents of satisfaction are dependent variables equal to 1 if satisfied and 0 otherwise. We estimate linear probability models.

	(1)	(2)	(3)	(4)	(5)	(6)
	Smoke	Cost	Safety	Time	Quality	Difficulty
Firewood collection (=1)	−0.09***	0.02	0.05***	−0.06***	−0.01	−0.06***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Firewood purchase (=1)	−0.06***	−0.29***	−0.00	−0.06***	−0.01	−0.07***
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
LPG for cooking (=1)	0.58***	−0.06***	−0.02	0.48***	0.08***	0.26***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Primary cook present (=1)	−0.04***	0.03***	0.04***	−0.02*	0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Constant	0.10***	0.57***	0.32***	0.13***	0.93***	0.48***
	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8563	8563	8563	8563	8563	8563
R^2	0.44	0.10	0.03	0.26	0.08	0.13

Standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 5
General comparison of subjective cooking arrangements across collectors. We estimate linear regressions, with higher values of the dependent variable indicating higher levels of satisfaction on a 0–2 scale. "Std" stands for standardized.

	(1)	(2)	(3)	(4)	(5)
Time spent per day to collect firewood, Std	−0.02			−0.00	−0.01
	(0.02)			(0.02)	(0.02)
Distance traveled per day to collect firewood, Std	0.01			0.01	0.02
	(0.02)			(0.02)	(0.01)
Firewood price (INR/kg), Std		−0.03**		−0.03***	−0.02**
		(0.01)		(0.01)	(0.01)
Distance to firewood market (km), Std		−0.02**		−0.04***	−0.03***
		(0.01)		(0.01)	(0.01)
LPG for cooking (=1)			0.50***	0.51***	0.30***
			(0.02)	(0.02)	(0.03)
Satisfaction with smoke (=1)					0.16***
					(0.03)
Satisfaction with cost (=1)					0.15***
					(0.02)
Satisfaction with safety (=1)					0.12***
					(0.02)
Satisfaction with time consumption (=1)					0.24***
					(0.03)
Satisfaction with quality (=1)					0.27***
					(0.03)
Satisfaction with difficulty (=1)					0.17***
					(0.02)
Primary cook present (=1)	−0.03	−0.05**	−0.04**	−0.05**	−0.04*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Constant	1.28***	1.29***	1.15***	1.15***	0.68***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)
State FE	Yes	Yes	Yes	Yes	Yes
Observations	6416	5608	6416	5608	5608
R^2	0.02	0.03	0.09	0.09	0.18

Standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

the inconvenience associated with purchasing firewood from rural markets as important determinants of dissatisfaction with one's cooking arrangements. Indeed, the coefficient on LPG use for cooking is still very high (0.54) and the one on distance to firewood market (standardized) is significant and negative (−0.05). The odd ratios in the ordered logit model and in the generalized ordered logit one confirm these remarks (Tables A21 and A26). In particular, the odd ratio for LPG use equals 5.53 in Model 4 and 3.42 in Model 5 (Table A26).[11]

By comparing these results to those for all households using firewood, we note that firewood price no longer has a large and significant coefficient.[12] At first sight, one might think that regular collectors assign less importance to firewood price, as they may collect firewood and chips instead of buying them. However, distance to firewood market has the same coefficient in this regression as in the one for the sample with all households using firewood. One interpretation could be that even though they collect firewood,

[11] LPG use variable satisfies the parallel lines assumption.

[12] Both the ordered logit model and the generalized one support this comment (Tables A21 and A26).

Table 6
General comparison of subjective cooking arrangements across regular collectors. We estimate linear regressions, with higher values of the dependent variable indicating higher levels of satisfaction on a 0–2 scale. "Std" stands for standardized.

	(1)	(2)	(3)	(4)	(5)
Time spent per day to collect firewood, Std	0.02			0.01	0.01
	(0.02)			(0.02)	(0.02)
Distance traveled per day to collect firewood, Std	0.01			0.01	0.02
	(0.02)			(0.02)	(0.01)
Firewood price (INR/kg), Std		0.00		−0.00	0.02
		(0.02)		(0.02)	(0.02)
Distance to firewood market (km), Std		−0.04***		−0.05***	−0.03**
		(0.01)		(0.01)	(0.01)
LPG for cooking (=1)			0.52***	0.54***	0.34***
			(0.05)	(0.05)	(0.06)
Satisfaction with smoke (=1)					0.09*
					(0.05)
Satisfaction with cost (=1)					0.17***
					(0.04)
Satisfaction with safety (=1)					0.17***
					(0.03)
Satisfaction with time consumption (=1)					0.26***
					(0.04)
Satisfaction with quality (=1)					0.26***
					(0.05)
Satisfaction with difficulty (=1)					0.18***
					(0.03)
Primary cook present (=1)	−0.09***	−0.07**	−0.09***	−0.08**	−0.10***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Constant	1.21***	1.19***	1.17***	1.13***	0.66***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.06)
State FE	Yes	Yes	Yes	Yes	Yes
Observations	2636	2453	2636	2453	2453
R^2	0.04	0.05	0.07	0.08	0.17

Standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

people still buy food or other tools that are required for cooking on that same market. Then, being closer to it would increase their satisfaction with their cooking arrangement even thought they do not buy firewood. A more thorough explanation is that regular collectors manage to adapt the amount they collect to counterbalance potential high prices of firewood on the market. The fact that they still go to the market explains the significance of the coefficient on market distance; but as they can adapt their purchases to the price, they do not give a significant importance to the price of firewood on that market. A counterargument could be that following this reasoning, demand for firewood would be very high when the price is high and could exceed the available supply from forests. In turn, households would have to spend more time collecting and use lower quality firewood. This explanation would contradict the fact that, in Table A30, interactions between daily distance/time for collection and market price are insignificant. However, Van't Veld et al.'s (2006) results agree with our theory as they argue that households in Madhya Pradesh do not adapt their time or distance spent on collection to market price but switch to firewood from private trees and to agricultural waste.

Another expected difference with the results obtained for all households using firewood is that subjective satisfaction with smoke becomes insignificant at the 5% level of significance.[13] Indeed, regular collectors are used to smoky biomass stoves and smoke does not impact their satisfaction with cooking arrangements anymore. However, they interestingly give more importance to safety than all households using firewood. The coefficient of satisfaction with safety is indeed 0.05 higher. We find similar findings when we do not control for LPG use. In this case, the coefficient on smoke satisfaction is one third lower in the regression on regular collectors (0.22) than in the ones on collectors and on all households (0.33) (Table A27) while the coefficient on safety satisfaction increases. Even though research has highlighted the harmful effects of cookstove smoke on health, it is not considered as a problem by regular users of firewood. Simultaneously, regular collectors seem to be more sensitive to perceived safety of the cookstove. Therefore, our result suggests that informing these people on the harmful effects of biomass cookstoves and on the safety of other cookstoves could influence their demand for other sources of energy for cooking. This conclusion is in agreement with Wijayatunga and Attalage (2003), who identify unawareness and risk as two main barriers to switching from biomass to LPG.

Results on policy preferences

To go beyond our analysis of satisfaction with cooking arrangements, we assess the link between the above subjective subcomponents and policy preferences for LPG. Policy preferences for LPG are measured by asking individuals to rank the importance of government support to households on items from a list including LPG, electricity, kerosene, clean water, and education. When the dependent variable equals 1, it means that the individual ranked it as the top priority for the government. On the contrary, when the dependent variable equals 5, it means that the individual ranked it as the last important priority for the government. Therefore, in our regressions, a *negative* coefficient can be interpreted as a correlation with higher support for LPG. Independent variables are the same as those included in the previous regressions. The same groups are studied: all households, collectors of firewood and regular collectors. With i denoting subjects, j denoting villages, and k denoting states, the linear regression equation can be written as follows:

$$\text{Policy Preference for LPG}_{ijk} = \alpha_k + \sum_c \beta_c x^c_{ijk} + \epsilon_{ijk} \quad (2)$$

[13] Both the ordered logit model and the generalized one support this comment (Tables A21 and A26).

where Policy Preference for LPG is the subject's reported ranking of LPG importance in terms of government support compared to other alternatives listed above (1–5), α_k is the state fixed effect, and x^c are covariates indexed by c. Finally, ϵ_{ijk} is an error term. Here again, we use cluster standard errors as well as survey weights to ensure that the sample is representative of the population.

In Table 7, we provide results for predictors of policy preferences among all households. The structure of the table is similar to those above, but it is important to remember that a negative coefficient means a *higher* ranking on a 1–5 scale. Contrary to our expectations, patterns of policy preferences differ from the ones of subjective overall satisfaction. Differences are mainly in the coefficients on the subjective sub-components of satisfaction and in the results for all and regular collectors. In the regression considering all households, firewood collection has an insignificant effect on policy preferences for LPG while firewood purchase is correlated with a higher ranking of LPG as a priority for the government. In Model 4, the coefficient magnitude is 0.08, which accounts for 6.8% of the standard deviation of the dependent variable describing policy preference for LPG.

As expected, the main predictor of policy preferences for LPG is the actual use of LPG. The latter variable has a negative coefficient of magnitude 0.35, which is about 30% of the standard deviation of the dependent variable. Interestingly, then, LPG use reflects ascribing *more* importance to LPG policy. In the meantime, non-LPG households are less interested despite their lack of access. These results are consistent with a mental model in which LPG users worry about the supply and cost of fuel, while non-users do not consider LPG a realistic prospect in their own situation, perhaps because of cost. In such a setting, the negative coefficient would stem from non-users considering LPG outside the realm of possibility, while LPG users would value policy because they worry about access and cost.

As opposed to the results for satisfaction with cooking arrangements, subjective sub-components of satisfaction are not significant on policy preferences except satisfaction with smoke. The latter coefficient is significant at the 1% significance level. It is worth noting that individuals who are satisfied with smoke are mainly the ones already using LPG or other modern cookstoves. Indeed, as shown in Table A5, correlation between LPG use and smoke satisfaction is 0.61, higher than the correlation between LPG use and any other subjective sub-category of satisfaction. These results are in agreement with our regression without controlling for LPG use (Table A27). However, Table 7 goes further and indicates that the satisfaction with smoke of a given household, using LPG or not, increases the likelihood that the latter supports LPG as a priority for the government. An explanation is that a household which is satisfied with smoke may already use a modern cooking stove even if it does not have access to LPG. To choose such a modern solution, this household might have an interest in improving its cooking arrangement in the short term and hence in energy policies in favor of LPG.

Table 8 shows the results for policy preferences among firewood collectors when estimating the linear regression. As above, the main predictor is LPG use with a negative coefficient of magnitude 0.21. In the regression, we also refined our assessment of firewood collection and purchase. This change unexpectedly affects our results, as both variables measuring firewood collection (traveled distance and time spent per day to collect firewood) have significant positive coefficients at the 5% level of significance. An increase in one standard deviation of one of these variables decreases the ranking of LPG by around 0.05 relative to the other options (4.3% of a standard deviation). A reason could be that people who are spending a lot of time collecting or traveling long distances to collect firewood are probably very used to doing so. Most of them might have built a routine around it and are used to cooking with biomass. Therefore, they might not consider LPG as a top priority for the government compared to other alternatives for which they may not have any access at all. Firewood price is still insignificant while distance to firewood market matters positively on LPG preferences. The same reasons than the ones mentioned for the above results in the analysis of satisfaction with cooking arrangements can explain these features. Finally, it is again surprising that none of the subjective measures of satisfaction has a significant effect on policy preference for LPG.

Table 7
Policy preferences results across all households. We estimate linear regressions, with higher values of the dependent variable indicating less priority of LPG policy on a 1–5 scale.

	(1)	(2)	(3)	(4)	(5)
Firewood collection (=1)	0.05			−0.04	−0.05
	(0.03)			(0.03)	(0.03)
Firewood purchase (=1)		-0.06**		−0.08**	−0.09**
		(0.03)		(0.04)	(0.04)
LPG for cooking (=1)			−0.35***	−0.35***	−0.27***
			(0.03)	(0.03)	(0.04)
Satisfaction with smoke (=1)					−0.14***
					(0.05)
Satisfaction with cost (=1)					−0.01
					(0.03)
Satisfaction with safety (=1)					0.04
					(0.03)
Satisfaction with time consumption (=1)					0.01
					(0.04)
Satisfaction with quality (=1)					−0.08
					(0.05)
Satisfaction with difficulty (=1)					0.02
					(0.03)
Primary cook present (=1)	0.08**	0.08***	0.07**	0.07**	0.06**
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Constant	3.36***	3.41***	3.52***	3.57***	3.64***
	(0.04)	(0.03)	(0.03)	(0.04)	(0.07)
State FE	Yes	Yes	Yes	Yes	Yes
Observations	8563	8563	8563	8563	8563
R^2	0.05	0.05	0.06	0.06	0.07

Standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 8
Policy preferences results across collectors. We estimate linear probability models, with higher values of the dependent variable indicating less priority of LPG policy on a 1–5 scale. "Std" stands for standardized.

	(1)	(2)	(3)	(4)	(5)
Time spent per day to collect firewood, Std	0.07***			0.05**	0.05**
	(0.02)			(0.03)	(0.03)
Distance traveled per day to collect firewood, Std	0.06***			0.06***	0.06***
	(0.02)			(0.02)	(0.02)
Firewood price (INR/kg), Std		−0.02		−0.02	−0.02
		(0.02)		(0.02)	(0.02)
Distance to firewood market (km), Std		−0.05***		−0.04**	−0.04**
		(0.02)		(0.02)	(0.02)
LPG for cooking (=1)			−0.28***	−0.21***	−0.20***
			(0.04)	(0.04)	(0.05)
Satisfaction with smoke (=1)					−0.08
					(0.07)
Satisfaction with cost (=1)					−0.03
					(0.04)
Satisfaction with safety (=1)					0.03
					(0.04)
Satisfaction with time consumption (=1)					0.04
					(0.05)
Satisfaction with quality (=1)					0.02
					(0.07)
Satisfaction with difficulty (=1)					0.06
					(0.04)
Primary cook present (=1)	0.03	0.12***	0.05	0.10***	0.10***
	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)
Constant	3.45***	3.36***	3.49***	3.46***	3.42***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.07)
State FE	Yes	Yes	Yes	Yes	Yes
Observations	6416	5608	6416	5608	5608
R^2	0.06	0.07	0.06	0.08	0.08

Standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Finally, in Table 9 we report results for regular collectors of firewood. Results are similar to the ones obtained with all collectors. In Model 4, coefficients' magnitude is similar even though the coefficient on LPG use is no longer significant at the 5% level of significance due to large standard errors. Adding sub-categories of subjective satisfaction, however, leads to some surprising differences in results. Indeed, regular collectors seem to be very sensitive to time consumption of the cooking arrangement as shown by the significant and positive coefficient on satisfaction with cooking time (0.19) in Model 5. Part of this difference can be explained by the high positive correlation between LPG use and satisfaction with speed of cooking.

Robustness

The results above are robust to replacing the state ($N = 6$) fixed effects with village ($N = 714$) fixed effects (Section A4.2) and to estimating ordered logistic regressions to account for the ordinal nature of the dependent variable (Section A4.3). We also use a generalized ordered logit model to relax some of the parallel lines assumptions and choose the partial proportional odds model that best fits the data (Tables 3, A25 and A26 in Section A4.4). The results are also virtually unchanged when we estimate models with an extensive array of control variables (Section A4.1).[14] In Table A28, we can also see that removing the control for the presence or not of the primary cook does not significantly affect our results.

In Section A5, we examine non-linear relationships between the predictors and the use of LPG. To study these relationships, we change the specification of Model 4 by adding interaction terms with the dummy variable accounting for the use of LPG. Results are shown in Table A29 and graphically represented in Fig. A3. The dependent variable in Models 1–3 is satisfaction and in Models 4–6 it is policy ranking. When we consider all households, the interaction term between LPG for cooking and firewood collection is significant at the 1% significance and its coefficient is equal to −0.12. The LPG use coefficient is even higher than in our base model (0.61). This negative interaction term probably reflects the fact that individuals who are forced to mix LPG and collecting are more unsatisfied than those using only LPG. This result may be linked to a lower satisfaction with time consumption or quality. When we consider collectors and regular collectors, none of the interaction terms is significant. Hence, previous main results are unchanged by adding interaction terms with the dummy variable reflecting LPG use. An additional specification is to add interaction terms with the variables related to firewood purchase. Table A30 shows the Model 4 specification with interaction terms of these continuous variables. The dependent variable is Satisfaction in models (1) and (2) and policy preferences for LPG for models (3) and (4). Here again, our results remain mainly unchanged and no interaction term is significant at the 5% level of significance.

In Tables A31–A34, we use threshold models of the regressions on collectors and regular collectors to account for potential nonlinearities around 0, such as those introduced by coding daily time and distance traveled for collection as zero for people collecting monthly or yearly. To do so, we introduce a dummy variable that equals 1 whenever distance for collection is zero (we do not add a variable that equals 1 when distance traveled for collection is equal to 0, because the latter would be equal to the former and generate multicollinearity problems). Moreover, as we may also suspect nonlinearities around 0 for the distance to market variable, we also introduce a dummy variable which is equal to 1 whenever distance to market is zero. Results are available in Tables A31 to A34. Note that in the regression on the sample of regular collectors, we only

[14] Control variables are the following: age; gender; education categories; number of adults and children in the household; religion dummy variables; caste dummy variables; yearly saving; and bank account dummy variable.

Table 9
Policy preferences results across regular collectors. We estimate linear probability models, with higher values of the dependent variable indicating less priority of LPG policy on a 1–5 scale. "Std" stands for standardized.

	(1)	(2)	(3)	(4)	(5)
Time spent per day to collect firewood, Std	0.04			0.03	0.03
	(0.03)			(0.03)	(0.03)
Distance traveled per day to collect firewood, Std	0.05**			0.05***	0.06***
	(0.02)			(0.02)	(0.02)
Firewood price (INR/kg), Std		−0.02		−0.02	−0.01
		(0.03)		(0.03)	(0.03)
Distance to firewood market (km), Std		−0.06**		−0.05**	−0.05*
		(0.02)		(0.02)	(0.03)
LPG for cooking (=1)			−0.28***	−0.18*	−0.29**
			(0.10)	(0.10)	(0.12)
Satisfaction with smoke (=1)					0.06
					(0.10)
Satisfaction with cost (=1)					0.06
					(0.06)
Satisfaction with safety (=1)					0.01
					(0.05)
Satisfaction with time consumption (=1)					0.19***
					(0.07)
Satisfaction with quality (=1)					−0.11
					(0.10)
Satisfaction with difficulty (=1)					0.09
					(0.06)
Primary cook present (=1)	0.04	0.08	0.05	0.07	0.07
	(0.05)	(0.06)	(0.05)	(0.06)	(0.06)
Constant	3.44***	3.46***	3.51***	3.43***	3.45***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.11)
State FE	Yes	Yes	Yes	Yes	Yes
Observations	2636	2453	2636	2453	2453
R^2	0.07	0.08	0.07	0.08	0.09

Standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

include the dummy variable relative to market distance. Indeed, by construction, the one characterizing collection is equal to 0 for all the observations in the regular collector sample. Even though the coefficients are less significant than in the main analysis, they mainly keep the same sign and order of magnitude.

Finally, we estimate a linear probability model assessing the probability for LPG to be ranked first or second in the importance of government support to households on items from a list including LPG, electricity, kerosene, clean water, and education (Table A36). In the latter, the only significant coefficient in Models 4 and 5 is the one on LPG use (0.04). It is consistent with the prominent role of LPG use in policy preferences for LPG that we mentioned above.

Discussion and conclusion

Our results underscore the valuation of modern energy access by rural households. Of all the different factors we consider, access to LPG is the best predictor of high values of subjective well-being. In fact, it remains a strong and robust predictor even if we control for various sub-components of subjective satisfaction. This result is important because it shows that efforts to provide households with access to modern cooking fuels are not just a paternalistic, top-down intervention. Instead, improved access to modern cooking fuels is greatly valued by the households themselves. Policies to improve access to modern cooking fuels would thus be popular among beneficiaries, provided the alternatives to traditional biomass are of high quality and meet the households' needs.

Another finding worth discussing pertains to the relative importance of the inconvenience of firewood collection and firewood purchases. Although firewood collection can consume a lot of time and is generally more demanding than firewood purchase, the households' subjective perception appears to be the opposite. Households seem not to mind the burden of firewood collection, as firewood is a free fuel for them. In contrast, they consider the trip to firewood markets to be inconvenient, as they must spend time and energy to go and spend scarce money on a basic necessity.

We also consider our results on the sub-components of satisfaction important. Based on our regressions, households appear to value reduction in smoke, speed of cooking and quality of meal more than other possible issues (cost, safety, and difficulty). In practice, if we want households to be satisfied with an alternative to biomass we should be sure that it presents the latter characteristics. Although LPG use shows a very strong correlation with the reduction of smoke and the speed of cooking, its correlation with satisfaction with the quality of meals is low. This lack of correlation together with the high cost of fuel may explain why LPG penetration still remains limited in rural India. Such results are important for both research on rural energy access and practitioners, as they offer an improved understanding of the psychology of cooking. A behavioral approach to understanding and promoting the use of modern cooking fuels to replace traditional biomass would benefit from recognizing the importance of these subjective components and focusing on interventions that meet the dual imperative of speed and quality.

Data and methods

Samples

The survey design and sampling are described in Section A1. For the analysis, we define three different samples:

- *All households*. All households with outcome data ($N = 8563$) are included.
- *Firewood users*. All households that use firewood ($N = 5608$) are included.

- *Regular collectors*. All households that collect firewood regularly ($N = 2636$) are included. By regularly we mean daily or weekly.

In all surveys, household heads were interviewed.

Outcome variables

The primary outcome variable measures the respondent's subjective satisfaction with their cooking arrangement on a 0–2 scale, with higher values indicating more satisfaction:

"So, overall how satisfied are you with your current primary cooking arrangement?"

The possible responses are "unsatisfied" (0), "neutral" (1), and "satisfied" (2). The options were given to the respondents in the survey, so that each respondent could anchor their view to the scale used. This question is posed only after the objective data about cooking arrangements and the basic sub-components of satisfaction with sub-components (dummy variables for satisfaction with smoke, cost, danger, time, quality, difficulty) are recorded. Based on several field pilots, we found that subjects find it easier to formulate a meaningful opinion about satisfaction after they have thought about the different dimensions of the issue. We also chose to give only three options because in the pilot study, many of our respondents faced major difficulties in choosing between more nuanced options, such as "very satisfied" versus "somewhat satisfied" on a standard 5-point Likert scale.

The secondary outcome variable is a ranking of the following five policy preferences: LPG, electricity, kerosene, clean water, and education. The respondent was requested to rank them with the help of colored cards. On a 1–5 scale, higher values indicate less priority for LPG supply relative to the others.

Explanatory variables

The explanatory variables are defined as follows:

- *Firewood collection* is a binary indicator (0/1) for firewood collection by members of the household. We build this variable from answers to two different questions. If individuals answered Yes to the question "Do you use firewood and chips for cooking?" and answered the next subquestion "How much [of the firewood used per week for cooking] is collected by household members in kg?" by a positive number, this variable is coded 1. If they answered Yes and 0 or No, we attribute the value 0. There are 2682 observations for which the dummy variable is equal to 0.
- *Firewood purchase* is a binary indicator (0/1) for firewood purchases by members of the household. It is built in the same way than the indicator for firewood collection except that the subquestion we take into account is the following: "How much [of the firewood used per week for cooking] is brought from the market in KG?".
- *LPG for cooking* is a binary indicator (0/1) for any use of LPG for cooking. It is created by coding of answers to "Do you use domestic gas (LPG) for cooking?" with 1 for Yes and 0 for No.
- *Satisfaction with smoke/cost/safety/time consumption/quality/difficulty* is a binary indicator (0/1) for the relevant dimension of subjective satisfaction. Households respectively answered the following questions by Yes or No: "The primary arrangement of cooking that you use: Produces excessive smoke?/Is too expensive to use?/Is too dangerous to use?/Is too time consuming?/Has good quality of cooking?/Is too difficult to use?". Then, we give Yes answers the value 1 and No ones the value 0 for their respective dummy variables.
- *Primary cook present* is a binary indicator (0/1) for the presence of the household's primary cook at the interview. It is reported by the interviewer and not asked to the household. In addition, the questionnaire highlighted at the beginning of the section concerning the cooking situation that the interviewer had to invite the household's primary cook to join the interview even if not household head.
- *Time spent per day to collect firewood, Std* is a standardized variable for the time that is spent per day by firewood collectors to collect firewood. This variable relies mainly on the answer to the question: "How much time do you spend each time you go for collection in Hours/collection?". This question is asked only to people who answered that their collection frequency for firewood was "Daily" or "A few times a week". For households collecting firewood daily, we assume one collection per day and consider the time per collection reported to the question above to be the time they spent per day to collect firewood. For household collecting firewood a few times a week, we assume that they were collecting firewood twice a week and multiply the previous answer by (2/7) to calculate daily time of collection.
- *Distance traveled per day to collect firewood, Std* comes from the standardization of the variable giving the distance that individuals in the households travel per day to collect firewood. The latter is calculated from answers to the question: "What is the one-way distance in kilometers your household typically travels to collect firewood and chips in km?". We multiply this distance by two so that the time spent on collection per day and the distance traveled daily for the same purpose are comparable. Then, we make the same assumption as above to build our variable. In particular, people collecting "a few times a week" are considered as collecting twice a week.
- *Firewood price (INR/kg), Std* is a standardized variable reflecting the price of firewood and chips. It is based on answers to the question: "How much does a Kg of firewood and chips cost in rupees?". This question was asked only to people using firewood for cooking. For the 3389 people who answered "I don't know", we make the assumption that they would go on the same market than other people in their village. Based on this assumption, we assume that the price they would face is about the mean of the price reported by people in their village. This assumption allows us to assign an approximated value of the price to 3052 observations.
- *Distance to firewood market (km), Std* is a standardized variable describing the distance traveled by the household to buy firewood and chips. It relies on answers to the question: "What is the one-way distance in kilometers your household typically travels to buy firewood and chips in km?". We multiply it by two to reflect the total distance in order to make it comparable to the variable we built for distance for firewood collection. For individuals who replied "I don't know", we use the same assumption than the one used for firewood price and approximate this distance by the average reported distance by people living in their village. This method allows us to infer 3149 values for the 3389 indecisive answers to this question. Note again that the last four continuous variables are standardized in order to make interpretation easier and coefficients comparable.

Statistical models

The main models are linear regressions with state fixed effects, sampling weights, and robust standard errors clustered to adjust for the sampling of subjects by village. The state fixed effects are included to ensure that our results are not driven by differences

in historical state policies and trajectories of socio-economic development. We do not include village fixed effects because much of the variation in both the explanatory and dependent variables occurs between, instead of within villages; another reason is that the state is the relevant unit for policy formulation on energy access. In the Appendix, we also report results with additional controls (Section A4.1), with village fixed effects (Section A4.2), and from ordered logistic regressions (Section A4.3). For robustness purposes, we also report results without controlling for the presence of the primary cook and with additional interaction terms as well as threshold models (Section A5). For the list and summary statistics of additional control variables, see Table A2.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.esd.2017.02.003. A replication archive is available at http://dx.doi.org/10.7910/DVN/39PEFW.

References

Aklin M, Cheng CY, Urpelainen J, Ganesan K, Jain A. Factors affecting household satisfaction with electricity supply in rural India. Nat Energy 2016;1:16170.

Aklin M, Cheng CY, Ganesan K, Jain A, Urpelainen J. Council on Energy, Environment and Water. Access to clean cooking energy and electricity: survey of States in India (ACCESS). Harvard Dataverse, V1.; 2016. http://dx.doi.org/10.7910/DVN/0NV9LF.

Bansal M, Saini RP, Khatod DK. Development of cooking sector in rural areas in India: a review. Renew Sustain Energy Rev 2013;17(1):44–53.

Barnes DF. Electric power for rural growth: how electricity affects life in developing countries. 2nd ed., Washington DC: Energy for Development; 2014.

Bookwalter JT, Dalenberg D. Subjective well-being and household factors in South Africa. Soc Indic Res 2004;65(3):333–53.

Budya H, Arofat MY. Providing cleaner energy access in Indonesia through the megaproject of kerosene conversion to LPG. Energy Policy 2011;39(12):7575–86.

Cheng C, Urpelainen J. Fuel stacking in India: changes in the cooking and lighting mix, 1987–2010. Energy 2014;76:306–17.

Das D, Srinivasan R. Income levels and transition of cooking fuel among rural poor in India. Energy Sci Technol 2012;4(2):85–91.

Dercon S, Christiaensen L. Consumption risk, technology adoption and poverty traps: evidence from Ethiopia. J Dev Econ 2011;96(2):159–73.

Diener ED, Emmons RA, Larsen RJ, Griffin S. The satisfaction with life scale. J Pers Assess 1985;49(1):71–5.

Dugoua E, Urpelainen J. Relative deprivation and energy poverty: when does unequal access to electricity cause dissatisfaction? Int J Energy Res 2014;38(13):1727–40.

Erikson R, Uusitalo H. The Scandinavian approach to welfare research. Int J Sociol 1986;16(3/4):177–93.

Heltberg R. Fuel switching: evidence from eight developing countries. Energy Econ 2004;26(5):869–87.

Heltberg R. Factors determining household fuel choice in Guatemala. Environ Dev Econ 2005;10(03):337–61.

International Energy Agency, World energy outlook. Paris: International Energy Agency; 2015.

Jain A, Ray S, Ganesan K, Aklin M, Cheng C, Urpelainen J. Access to clean cooking energy and electricity: survey of states. New Delhi: Council on Energy Environment and Water; 2015.

Levine DI, Beltramo T, Blalock G, Cotterman C. What impedes efficient adoption of products? Evidence from randomized variation in sales offers for improved cookstoves in Uganda. Working paper series, Institute for Research on Labor and Employment. Berkeley: University of California2012.

Lewis JJ, Pattanayak SK. Who adopts improved fuels and cookstoves? A systematic review. Environ Health Perspect 2012;120(5):637–45.

Masera OR, Saatkamp BD, Kammen DM. From linear fuel switching to multiple cooking strategies: a critique and alternative to the energy ladder model. World Dev 2000;28(12):2083–103.

Mobarak AM, Dwivedi P, Bailis R, Hildemann L, Miller G. Low demand for nontraditional cookstove technologies. Proc Natl Acad Sci 2012;109(27):10815–20.

Pandey VL, Chaubal A. Comprehending household cooking energy choice in rural India. Biomass Bioenergy 2011;35(11):4724–31.

Parikh J, Balakrishnan K, Laxmi V, Biswas H. Exposure from cooking with biofuels: pollution monitoring and analysis for rural Tamil Nadu, India. Energy 2001;26(10):949–62.

Parikh P, Chaturvedi S, George G. Empowering change: the effects of energy provision on individual aspirations in slum communities. Energy Policy 2012;50:477–85.

Action Practical. Poor people's energy outlook. Rugby, UK: Practical Action Publishing; 2014.

SE4ALL, Global tracking framework: overview. World Bank Report for Sustainable Energy for All.; 2014, http://www.worldbank.org/en/topic/energy/publication/Global-_Tracking-_Framework-_Report.

Sehjpal R, Ramji A, Soni A, Kumar A. Going beyond incomes: dimensions of cooking energy transitions in rural India. Energy 2014;68:470–7.

Subramanian M. Deadly dinners. Nature 2014;509:

Takama T, Tsephel S, Johnson FX. Evaluating the relative strength of product-specific factors in fuel switching and stove choice decisions in Ethiopia: a discrete choice model of household preferences for clean cooking alternatives. Energy Econ 2012;34(6):1763–73.

Terrado EN. Pilot commercialization of improved cookstoves in Nicaragua. World Bank Report.; 2005.

Van't Veld K, Narain U, Gupta S, Chopra N, Singh S. India's firewood crisis re-examined. RFF discussion paper. 2006.

Wijayatunga, Attalage. Analysis of rural household energy supplies in Sri Lanka: energy efficiency, fuel switching and barriers to expansion. Energy Convers Manage 2003;44:1123–30.

Yadama GN. Fires, fuel, and the fate of 3 billion: the state of the energy impoverished. New York: Oxford University Press; 2013.