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Household energy access and expenditure in developing countries: Evidence from India, 1987–2010☆

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ABSTRACT

Although most studies of energy poverty focus on whether or not households have access to modern fuels, expenditure is also an important issue, as households in developing countries spend a significant proportion of their total expenditures on energy. Using nationally representative household data from India, 1987–2010, this article describes and explains trends in household energy expenditure. While monthly household spending on energy has increased in many Indian states, this change is not driven by increased household affluence. Statistical analysis shows that when modern fuels (LPG for cooking, electricity for lighting and appliances) are available, households are willing and able to spend on energy. Indian households that have seen improved access to LPG and electricity have also seen much higher energy expenditures, whereas increased household incomes do not explain greater spending on household energy. For policymakers, the key lesson is that programs to improve access to modern fuels allow both wealthy and poor households to spend money on valuable energy services.

Introduction

While most studies of household energy use in developing countries have focused on access to modern fuels (Masera et al., 2000; Pachauri and Spreng, 2004, 2011; Onyeji et al., 2012; Cheng and Urpelainen, 2014; Burke and Dundas, 2015), variation in household energy spending is another important dimension of the broader problem of energy poverty. In many developing countries, access to modern fuels, such as LPG and electricity, has improved significantly over the past decades. For example, the Electricity Access Database for the 2014 *World Energy Outlook* (IEA, 2014) shows that 91% of the urban and 64% of the rural population in developing countries now have electricity at home. Furthermore, about one-half of the population in developing countries has already moved away from using traditional biomass for cooking.

While these improvements in access to modern fuels are welcome due to evidence of their positive socioeconomic effects (Bernard, 2010; Andadari et al., 2014), policymakers also need to consider household energy expenditures. If households use a large proportion of their available income on modern energy, then energy access carries a high opportunity cost. If the energy cost burden were high among the poor in particular, then policymakers could consider policies to improve the affordability of energy. Moreover, the analysis of household energy expenditure should be of interest to social scientists. As modern fuels become accessible, households must decide how much of their (usually scarce) resources to allocate to energy spending. This resource allocation has implications for the socioeconomic benefits of energy access. For example, a very low level of spending in an environment characterized by widespread access to fuels would mean that households do not value modern energy, even when it is available, unless prices are very low due to generous subsidies or other government policies. Conversely, a very high level of spending would mean that households are forgoing many other consumption opportunities because of their energy needs. Explaining variation in household energy spending provides useful information about both willingness to pay and the social benefits of increased energy expenditure.

The available data underscore the importance of explaining variation in household energy spending. Overall, households in developing countries spend a relatively high proportion of their disposable income on fuel. Even in middle-income countries, household energy remains a budget item worth consideration; for instance, energy expenditures account for 3.4% of household expenditure in Brazil and 4.7% in South Africa (Winkler et al., 2011). In poorer countries, household energy expenditures account for a larger share of the total. In Bangladesh, over 40% of households spend greater than 10% of their total income on energy (Barnes et al., 2011), placing them above the 10% threshold that is widely used to indicate energy poverty in terms of affordability (Pereira et al., 2010; Winkler et al., 2011). In India, the 66th round of

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the National Sample Survey (NSS) shows that the mean percentage of household expenditure spent on energy in 2010 was 13.2%. These numbers suggest that understanding variation in household energy expenditures is important for understanding the overall household budget, as poor households tend to spend more than one-tenth of their expenditures on energy.

What determines variation in energy spending across households? Why do some households spend more than others? Does increased energy spending reflect a high willingness to pay, even by the poor, for a service as it increasingly becomes available? The literature on energy poverty in developing countries has little to say about the sources of variation in household energy expenditures. While some studies discuss household energy spending as a share of total expenditures, their research methods do not provide conclusions about the factors associated with variation in energy spending. Winkler et al. (2011), for example, provide descriptive statistics on energy prices and spending for Bangladesh, Brazil, and South Africa, but they do not try to describe or evaluate the reasons for variation in household energy expenditures. Khandker et al. (2012) find that energy expenditures are positively associated with income among Indian households, except for the very poorest sectors of society, in the 2004–2005 wave of the India Human Development Survey. However, cross-sectional survey analysis cannot point to the determinants of variation in energy spending: perhaps poor people are unable or unwilling to pay, but it is also possible that they live in areas that do not have infrastructure and markets – access, writ large – to modern energy. Additionally, there is a large body of literature from industrialized and transition countries focusing on “fuel poverty” (Fankhauser and Tepic, 2007; Roberts, 2008; Moore, 2012; Walker and Day, 2012). However, it is unclear if these findings from generally affluent societies apply in the developing world.

In this article, we shed light on the above questions in the Indian context. We do not make causal claims, providing correlational and descriptive evidence for the factors driving variation. To do so, we use nationally representative survey data from the period 1987–2010 to describe and explain variation in household energy expenditure. The Indian context is ideal for such an analysis for three reasons. First, India is widely considered to be one of the countries facing the greatest challenges in providing affordable and widely available energy access in the form of modern fuels (Pachauri et al., 2004; Balachandra, 2011). It is therefore both a hard case and an important one. Second, there has been substantial variation in the performance of Indian states in providing access to modern fuels, and in fostering economic growth overall. These energy access differences are the product of both market variations and the significant policy autonomy of Indian states (Jenkins, 2004; Sinha, 2005). This variation allows us to explore the impact of energy access, while keeping macroeconomic trends and other national-level variables constant. Considering energy access as one component of multidimensional poverty evaluation, this analysis also furthers research into both the domain-specific and geographically-specific dimensions of poverty in India (Alkire and Seth, 2015). Third, the NSS dataset allows us to make the analytically crucial distinction between urban and rural trends. Scholars have emphasized that India's rural poverty has been particularly sensitive to local conditions and policies, with national policies increasingly irrelevant for determining outcomes for the rural poor (Krishna and Shariff, 2011). We can further consider these arguments in the particular case of energy access and affordability.

This article has two major goals. First, we describe the patterns of change in the energy cost burden in rural and urban India between 1987 and 2010. We measure the energy cost burden as the share of total expenditures that are allocated to energy. The burden is light if the share of energy in expenditure is low and heavy if the share is high. We characterize the previous (1987) and current (2010) conditions with a focus on both variation across states and between rural and urban households. This analysis is important because previous studies do not provide a clear characterization of changes over time and variation across geographies. The descriptive approach in our article also lays the foundation for future studies of household energy expenditures in India and other developing countries.

Second, we examine the relationship between household expenditure, modern energy access, and the energy cost burden at the household level. Our descriptive analysis clearly shows that, over time, the energy cost burden in India has increased, as households – especially in rural areas – spend more money on energy than ever before. Therefore, it is important to understand why the energy cost burden has changed. Existing studies have not provided explanations for variation in household energy spending, leaving open the key question of whether high levels of spending indicate a burden on households or, more encouragingly, a high willingness to pay for modern energy services. Without an answer to this question, it remains unclear whether policymakers should focus on reducing energy prices or on increasing levels of access to often relatively expensive modern fuels.

Materials and methods

The National Sample Survey (NSS) Organization, established in 1950, is an Indian Government agency responsible for running a number of nationally representative surveys, including one survey, administered approximately twice every 10 years, measuring expenditures at the household level. Equipped with sampling weights, the data are representative both at the national level and within each state. Moreover, the data are representative for rural and urban households separately, allowing us to calculate distinct urban and rural energy cost burdens. Rural and urban areas are defined in the NSS; since the rural and urban samples are constructed separately, every household is either classified as rural or as urban, and every state has both rural and urban households.

For comparability of data and reliability, our analysis focuses on five rounds of the NSS, spanning the years from 1987 to 2010. Specifically, the rounds are the 43rd (1987), 50th (1993), 55th (1999), 61st (2005), and 66th (2010). Because of the depth of details on household energy expenditure and prices paid, we are able to analyze changing dynamics of energy poverty, access, and the energy cost burden during a recent and dynamic period in India's development. Overall, the surveys cover 578,066 households across all states and union territories India.

We use the survey both to provide descriptive statistics and to conduct regression analysis. We begin by describing patterns of energy cost burden in India, focusing on rural–urban, cross-state, and temporal variation. We then estimate regression models to explore linkages between household income, access to modern fuels, and household energy expenditures. Our descriptive and analytic models provide a clear view and explanation for the evolving situation in India.

Measuring the energy cost burden

The first goal of this article is to characterize the economic burden of household energy expenditure in rural and urban India. We analyze representative data on types of energy consumed, prices paid, and overall energy cost burden. Our data are nationally representative for rural and urban areas in all Indian states, allowing us to paint a clear picture of patterns of energy affordability in India.

To describe the energy cost burden in India, we begin with a measure for a household's energy expenditure, constructed by computing the ratio of energy expenses to total household expenditures on a monthly basis, for any given household, *i*:

$$\text{Energy Cost Burden}_i = \frac{\text{Energy Expense}_i}{\text{Total Expense}_i}.$$

This variable falls on the [0,1] range and captures a household's energy expenditure burden. Because the energy cost burden is defined as the share of total expenditure spent on energy, higher values indicate lower levels of energy affordability. The energy cost burden may improve either because the energy expense decreases or because total household expenditures increase, suggesting a positive income coefficient.

To construct the denominator, we use household expenditure data for the past 30 days, as reported by the interviewee. The expenditure data are collected by requesting that the interviewee state how many rupees the household has spent during the 30-day recall period on various goods and services, selected from a comprehensive list. These data are measured in Indian rupees and from the NSS. To construct the numerator, we sum over the 30-day expenses, again in Indian rupees, of all non-trivial energy sources used in India: firewood and chips, dung cakes, kerosene, electricity, and liquefied petroleum gas (LPG).

We do not have data to distinguish between energy purchases from a shop and energy produced at home. However, the NSS data do provide an overall estimate that captures both purchased and produced energy. For produced energy, a cost is imputed based on prevailing market prices. Importantly, this means that the energy cost burden for home production – in practice, firewood collection – must be thought of as forgone revenue. Because there is no explicit cash transaction, the household can be seen as losing revenue that sales of firewood would allow in local markets. From the perspective of the household's total budget, however, the implication remains the same: firewood collection for own use is firewood not sold for revenue. Our energy cost burden measure is adjusted such that it includes imputed costs for non-market transactions. This adjustment is important because many households in rural India remain dependent on firewood collection.

An important caveat to this approach is that it does not consider fixed costs, such as connection fees for electricity connections or LPG stove installation. Our focus here is only on continued energy expenditure on fuels, as opposed to the totality of spending. Clearly, high connection fees for electricity or LPG connections prevent the poor from gaining access to modern fuels and induce an association between household income and spending. Unfortunately, the data we have does not allow us to address this issue.

Household income, availability of modern fuels, and the energy cost burden

What explains variation in the energy cost burden? First, higher levels of household income could reduce the energy cost burden. Higher household incomes allow families to keep energy expenditure constant while spending a lower proportion of their income on energy. As household incomes increase, households could choose to allocate a lower share of their expenditure to basic energy needs. Since energy is a basic need, poor households are forced to use a larger share of their total expenditure to meet their energy requirements. Wealthier households, on the other hand, can more easily reach their preferred level of energy use and then use the remaining income for other purposes. In line with this argument, research by Khandker et al. (2012) finds that energy expenditures increase relatively slowly with income in a 2004–2005 cross-sectional survey of Indian households.

The second explanation for variation in energy cost burden is access to modern fuels. Greater access to more efficient modern fuels also allows families to move away from traditional sources such as firewood, dung, and kerosene, which are often associated with health problems and other negative effects on well-being (Kaygusuz, 2011; Burke and Dundas, 2015). In this case, access to modern fuels would increase the energy cost burden. If improvements in infrastructure, government policy, and private markets help households gain access to modern fuels, they could then achieve a higher level of energy access than was previously possible, by increasing energy expenditures as a portion of their budget.

The two explanations have very different analytic, normative, and policy implications. If low incomes are a strong predictor of a high energy cost burden, then energy prices are a serious impediment to access to modern services for the poor. If accessibility is key, then even the poorest are able to enjoy modern energy services despite their limited incomes. Of course, both explanations could be true at the same time. Furthermore, it is important to consider the difference between cooking and lighting fuel. In the case of cooking fuel, a low energy cost among the poor may reflect the availability of free or inexpensive firewood; in the case of lighting, however, kerosene expenditures could be high, especially if subsidized kerosene is not readily available. In this sense, the association between income and energy expenditures should be stronger for cooking than for lighting fuel.

Regression analysis for explaining household energy expenditures

We conduct a regression analysis to investigate the role of rising household incomes and increased access to modern fuels in explaining household energy expenditures. For the analysis, we cannot use energy cost burden as the dependent variable and household income as the predictor variable since both variables are functions of the household income variable. However, we can explain household energy expenditures as a function of non-energy expenditures. Since energy expenditure is, in virtually all cases, a fraction of total expenditure, the non-energy expenditure provides us with an excellent indicator for household affluence. The income hypothesis predicts that energy expenditures either remain stable as non-energy expenditures increase, or at best increase slowly; the access hypothesis predicts that energy expenditures increase with improved accessibility of modern fuels.

We estimate the average energy expenditure using the non-energy expenditure (a proxy for household income) and a binary indicator for use of LPG and/or electricity (direct measure of access to modern fuels). Energy expenditure is the average amount spent by households on electricity, dung cakes, LPG, kerosene, and firewood in the past 30 days. Non-energy expenditure is calculated as the amount of the non-energy household expenditure in the past 30 days. While the NSS does not provide information about income itself, non-energy expenditure is an excellent proxy for the ability of an Indian household to spend money. We account for inflation across the different NSS rounds by deflating the expenditure values using inflation of the consumer price index (CPI). The CPI was obtained from the IMF World Economic Outlook.[1]

With i indexing households clustered under states j and survey rounds k, the full estimation equation is below:

$$\begin{aligned}\text{Log}(\text{Energy Expenditure})_{ijk} = \beta_0 + \beta_1 * \text{Log}(\text{Non}-\text{Energy Expenditure})_{ijk} + \\ \beta_2 * \text{LPG Accessibility}_{ijk} + \beta_3 * \text{Electricity Accessibility}_{ijk} + \\ \beta_4 * X_{ijk} + \alpha_{jk} + \epsilon_{ijk},\end{aligned}$$

where $\text{Log}(\text{Energy Expenditure})_{ij}$ is the logarithm of energy expenditure in household i within state j and round k, and $\text{Log}(\text{Non-Energy Expenditure})_{ij}$ is the logarithm of non-energy expenditure in household i within state j and round k. We use the logarithm of these two variables because the statistical distributions are skewed and normality is a requirement for linear regression estimation. $\text{LPG Accessibility}_{ijk}$ and $\text{Electricity Accessibility}_{ijk}$ are two indicators that capture whether the household uses LPG and/or electricity. Lastly, α_{jk} contains state-round fixed effects, and ϵ_{ijk} is the error term. In all models, we compute robust standard errors.

Energy expenditure levels could be influenced by a number of other factors, so X_{ijk} is a matrix of control variables that includes household size (average number of people), household head age (average in years), female household head (proportion of households), and land

[1] Indicator available at http://www.econstats.com/weo/CIND.htm, accessed August 1, 2016.

ownership (mean acres). Cheng and Urpelainen (2014) provide a detailed discussion of these factors in the context of NSS data, and we follow their general empirical strategy. For instance, larger, extended households could consume higher levels of energy compared to smaller, more nuclear families. In addition, an older household head might also be more likely to hang on to traditional practices of energy use and expenditure compared to a younger household head. Similarly, a female household head could make different energy choices than a male household head. Households with higher levels of land ownership could consume more energy than landless households.

Energy expenditure could also depend on the price of different fuels. For example, if there is a substantial increase in the price of electricity or LPG, then access to these energy sources may not necessarily influence the level of energy expenditure. Moreover, this could result in households reducing their energy expenditure. Conversely, a fall in the prices could result in households increasing their energy expenditure conditional on access. We include state-round fixed effects throughout our analyses to control for prices, and any other relevant contextual factors at the state level during any given round, such as energy policy.[2]

In the analysis, β_1, β_2 and β_3 and are our main quantities of interest: β_1 gives us how energy expenditure changes with non-energy expenditure, whereas β_2 and β_3 show how LPG and electricity access relate to energy expenditure. Continuous variables are logarithmized whenever their distributions are skewed.

The above regression equation is used to estimate models for the full sample of households as well as the urban and rural households separately. Table 1 presents the summary statistics for all variables used, broken down for the full, urban and rural sample at the household level. As the tables show, data coverage is excellent and there is considerable variation between rural and urban households.

Table 1
Summary statistics (unweighted) for the full, urban and rural samples at the household level.

Full sample					
	Mean	sd	Min	Max	Count
Energy expenditure (Log)	5.86	0.73	-0	9	576,877
Non-energy expenditure (Log)	8.32	0.84	-3	13	576,480
LPG access (indicator)	0.24	0.43	0	1	578,066
Elec access (indicator)	0.63	0.48	0	1	578,066
Household size	4.94	2.53	1	24	577,866
HH age	44.86	13.65	1	95	577,746
Female HH (indicator)	0.10	0.30	0	1	578,066
Land (log)	2.39	2.48	-2	14	497,260
Urban sample					
	Mean	sd	Min	Max	Count
Energy expenditure (log)	5.98	0.76	−0	9	219,231
Non-energy expenditure (log)	8.46	0.87	−2	13	219,091
LPG access (indicator)	0.40	0.49	0	1	219,776
Elec access (indicator)	0.78	0.42	0	1	219,776
Household size	4.58	2.41	1	23	219,747
HH age	44.44	13.69	1	95	219,683
Female HH (indicator)	0.11	0.31	0	1	219,776
Land (log)	0.61	1.90	−2	12	160,721
Rural sample					
	Mean	sd	Min	Max	Count
Energy expenditure (log)	5.78	0.70	−0	9	357,646
Non-energy expenditure (log)	8.23	0.81	−3	13	357,389
LPG access (indicator)	0.15	0.35	0	1	358,290
Elec access (indicator)	0.55	0.50	0	1	358,290
Household size	5.16	2.58	1	24	358,119
HH age	45.12	13.62	1	95	358,063
Female HH (indicator)	0.10	0.30	0	1	358,290
Land (log)	3.25	2.27	−2	14	336,539

Results

We now present the results of the analysis.

Trends and variation in energy cost burden

Despite the importance of cross-state variation, our data show that the dynamics of urban and rural energy access play important roles in determining the energy cost burden. Table 2 provides a full overview of the cost burden of energy in 1987 and 2010 across all Indian states. In the columns, higher values indicate a higher energy cost burden or change thereof. The colored columns show the change between 1987 and 2010 as a proportion of the baseline.

The rural–urban divide is an important predictor of energy cost burden, as seen in Table 2. For instance, in Andhra Pradesh, the rural cost burden increased by 35% while the urban burden decreased by 23%; a similar situation characterizes Orissa. In other states, although the energy cost burden increases in both rural and urban areas, the rural increase is much greater: 71% for rural areas of Madhya Pradesh, for example, compared to a 10% increase in urban areas. Clearly, rural/urban divides as well as state-level divergence are important.

Fig. 1 shows the change in energy cost burden between 1987 and 2010 for rural India. As the upper panel shows, the average rural household allocates between 10 and 15% of their monthly expenditure to energy in any given survey year. Over time, the energy cost burden has increased for rural households. This reflects both inflation, as energy prices have grown over time, and the increased accessibility of modern fuels in rural areas. For example, in 1987, during the 43rd round of the NSS, only 31% of rural households had an electricity connection and only 6% had an LPG connection. In 2010, during the 66th round, these numbers had increased to 73% and 24%, respectively (the NSS data also show that more households rely on electricity and LPG as their primary lighting and cooking fuels).

For urban households, the situation is characterized in the lower panel of this figure. Here, the picture is less even. Many urban areas already had relatively high household incomes, along with good access to LPG and electricity, in 1987. Compared to rural areas, the changes are less dramatic over time.

We next present two separate maps that illustrate the wide variation in energy cost burden across both space and time. The map on the left of Fig. 2 presents the distribution of energy cost as a fraction of the household total expenditure in the 43rd round (1987). There is not much variation among the different states, with most of them using less than 13% of the household expenditure for energy. The map on the right presents a similar picture for round 66 (2010). Here, we see a wider variation in the energy cost burden with the households in the states of Madhya Pradesh, Chhattisgarh and Orissa using at least 15% of their expenditure for energy use. Notably, the poor states of the Hindi heartland (e.g. Bihar, Uttar Pradesh) do not see much change. At the same time, the energy cost burden is actually reduced in the wealthier and more developed states of the south (Kerala and Tamil Nadu).

To summarize, the analysis reveals considerable variation between rural and urban areas, between states, and over time. Interestingly, it is neither the poorest nor the wealthiest states have seen the largest increases in their energy cost burden. Instead, it is the middle range that seems to be increasing energy expenditures. We suggest thee explanations for these phenomenon. First, we note that relative changes in energy cost burden across states may be partially explained by changes in the relative percentage of the poor over time. To examine this, we consider the changes in the rupee-cutoff for the lowest quartile of the population by non-energy expenditures in rounds 43 and rounds 66.

[2] One control variable we cannot include is a household's stock of domestic appliances, as earlier rounds of the NSS data do not contain this information. However, we note that the electricity access indicator allows us to compare energy expenditure between households with no electric appliances (because they do not have an electricity connection) and households with the average number of electric appliances.

Table 2
Changes in energy cost burden by state, separately for rural and urban households, 1987–2010. The first two columns represent the cost burden of energy in rural areas in 1987 and 2010, respectively. The third column shows the change over time and the fourth in relative terms. Similarly, columns five and six represent the cost burden of energy in urban areas in 1987 and 2010, respectively, and the last two columns show the change over time. The values for Chhattisgarh (Madhya Pradesh), Daman & Diu (Goa), Jharkhand (Bihar), and Uttarakhand (Uttar Pradesh) are missing because these states did not exist in 1987. The other missing values reflect lacking data.

	43 Rural	66 Rural	Δ 66	%	43 Urban	66 Urban	Δ 66	%
Andaman & Nicobar Islands	0.11	0.07	-0.04	-38	0.23	0.06	-0.17	-73
Andhra Pradesh	0.10	0.13	0.03	35	0.14	0.11	-0.03	-23
Arunachal Pradesh	0.11	0.12	0.00	4	0.16	0.13	-0.03	-20
Assam	0.09	0.12	0.02	24	0.13	0.12	-0.02	-14
Bihar	0.12	0.12	0.00	3	0.12	0.13	0.01	12
Chandigarh	0.18	0.13	-0.06	-32	0.14	0.08	-0.06	-43
Chhattisgarh	.	0.18	.	.	.	0.13	.	.
Dadra & Nagar Haveli	0.12	0.11	-0.00	-1	.	0.11	.	.
Daman & Diu	.	0.07	.	.	.	0.10	.	.
Delhi	0.11	0.13	0.02	18	0.14	0.14	-0.00	-3
Goa	0.12	0.10	-0.02	-17	.	0.09	.	.
Gujarat	0.11	0.13	0.02	18	0.11	0.11	-0.00	-1
Haryana	0.08	0.12	0.04	52	0.14	0.13	-0.01	-8
Himachal Pradesh	0.11	0.13	0.02	15	0.11	0.11	0.00	1
Jammu & Kashmir	0.11	0.10	-0.01	-10	0.10	0.09	-0.01	-14
Jharkhand	.	0.14	.	.	.	0.10	.	.
Karnataka	0.12	0.14	0.02	15	0.12	0.11	-0.01	-7
Kerala	0.11	0.10	-0.01	-5	0.14	0.10	-0.04	-31
Lakshadweep	0.15	0.09	-0.06	-41	.	0.10	.	.
Madhya Pradesh	0.11	0.19	0.08	71	0.12	0.13	0.01	10
Maharashtra	0.11	0.14	0.04	34	0.12	0.12	-0.00	-4
Manipur	0.08	0.12	0.04	54	0.11	0.11	0.00	3
Meghalaya	0.12	0.11	-0.01	-7	0.16	0.10	-0.06	-39
Mizoram	0.10	0.12	0.02	18	.	0.09	.	.
Nagaland	.	0.08	.	.	0.13	0.09	-0.04	-32
Orissa	0.13	0.20	0.07	59	0.14	0.13	-0.01	-4
Pondicherry	0.10	0.08	-0.02	-20	.	0.09	.	.
Punjab	0.11	0.12	0.01	11	0.13	0.15	0.02	16
Rajasthan	0.09	0.13	0.05	55	0.11	0.12	0.01	9
Sikkim	0.10	0.13	0.04	36	0.11	0.08	-0.02	-20
Tamil Nadu	0.15	0.12	-0.03	-20	0.16	0.10	-0.06	-36
Tripura	0.12	0.14	0.01	11	0.15	0.10	-0.05	-33
Uttar Pradesh	0.11	0.14	0.02	22	0.16	0.12	-0.04	-23
Uttarakhand	.	0.13	.	.	.	0.12	.	.
West Bengal	0.11	0.14	0.03	24	0.18	0.12	-0.05	-30

Relative changes in this first difference provide an approximate measure of the relative changes in poverty across the states. These first differences are negatively correlated with changes in the energy cost burden (−0.78 for rural and −0.79 for urban, both p-values <0.001). This measure suggests that state-wise differences across time may be at least partially a result of relative changes to the income distributions.

Second, we note a general decline in the energy cost burden in urban areas across almost all states. This is expected, given the robust economic growth of the past few decades, leading to rising incomes in urban areas, and to the relative lack (or low level) of subsidies in urban areas in Round 43 (1987). Indeed looking at changes within states, for those with rural and urban data available in Round 43, the urban energy cost burden was higher than the rural burden in 21 states/UTs, and lower in only two (Chandigarh and Jammu and Kashmir; the energy cost burden is also essentially the same in two others). By Round 66, however, the rural cost burden is higher than the urban cost burden in 26 out of 35 States/UTs.

Third, we note that the largest increases in the energy cost burden seem to occur in states that have been successful in partially or fully reforming their power sectors, while most decreases in the energy cost burden have occurred in those states where reform has been limited or unsuccessful. This is consistent with a cost-burden logic in which it is precisely in those states in which power sectors have been reformed that consonant price changes, reflecting increased costs, have led to

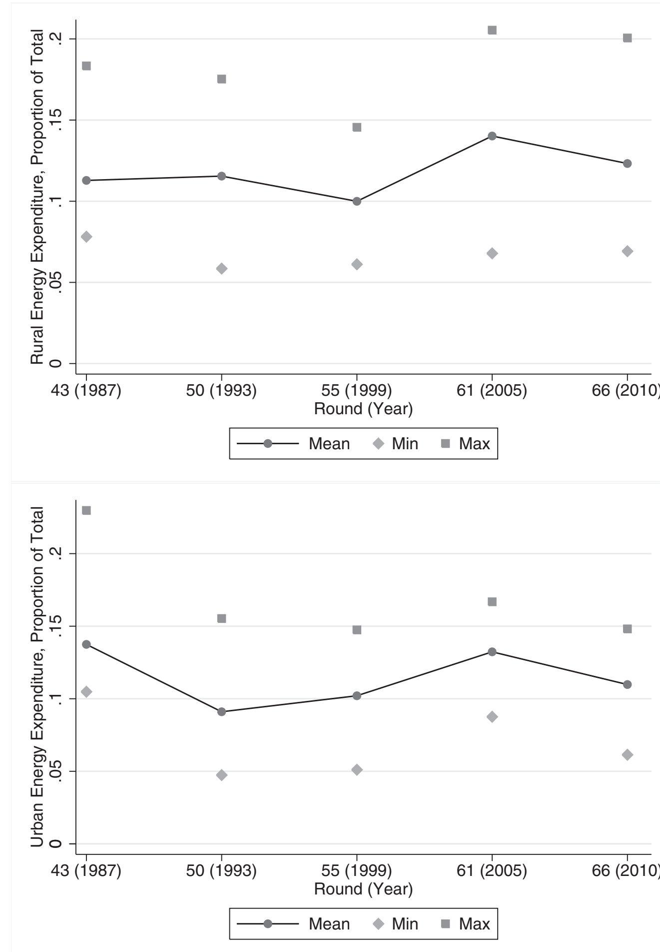

Fig. 1. Share of energy in total monthly household expenditure for rural and urban households in India, 1987–2010. The figures show the mean as well as the maximum and minimum state-level values for each round.

increases in energy expenditure and therefore increases in the energy cost burden.[3] Empirically, the trends in Rounds 43–66 do seem to be aligned with comparative reform success across Indian States, including an analysis of reform in the 20 largest states which groups reform according to "Complete Success", "Partial Success", and "Failure" (Cheng et al., 2016). For instance, three states with complete success see moderate increases in the rural energy cost burden (NCT of Delhi, Gujarat, and West Bengal), while those states with partial reforms include those with the highest increases in the rural energy cost burden (e.g. Haryana, Madhya Pradesh, Orissa, Rajasthan). Conversely, for the states that are deemed to be reform failures, and for which the NSS has data in both rounds 43 and 66, we see that the rural energy cost burden actually decreases (Kerala and Tamil Nadu) or increases only slightly (Bihar) or moderately (Uttar Pradesh).

Household income, availability of modern fuels, and energy cost burden

Fig. 3 presents a pair of scatter plots of rural and urban energy cost burdens against non-energy household expenditure at the state-round level. The decline in the energy cost burden, for both rural and urban households, is consistent with the notion that relative cost burden for energy is highest for those households with the lowest incomes. In other words, as hypothesized, increasing non-energy expenditures need not be accompanied by increased energy expenditures.

[3] We thank an anonymous reviewer for pointing to this explanation.

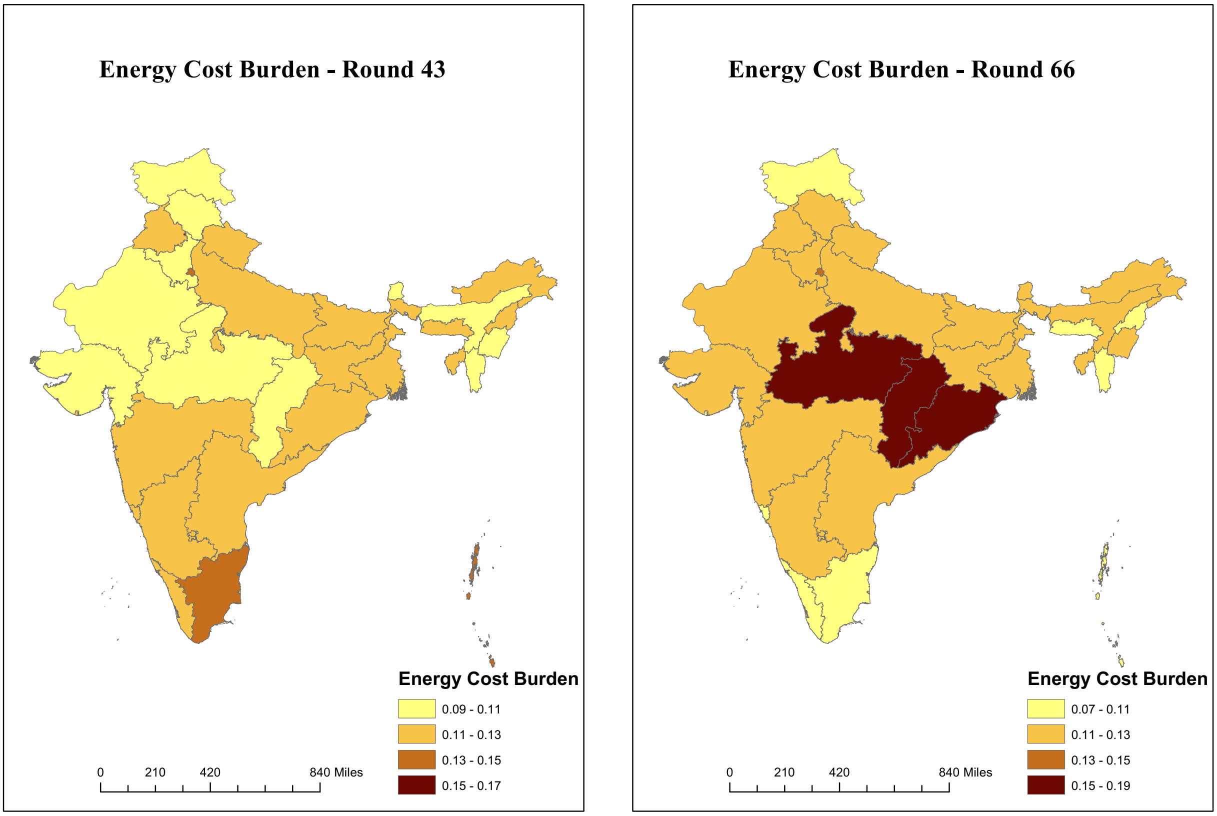

Fig. 2. Energy cost burden by state during rounds 43 (left, year 1987) and 66 (right, year 2010) of the NSS. Chhattisgarh, Daman & Diu, Jharkhand, and Uttarakhand did not exist in 1987. Their values are based on values for the states of Madhya Pradesh, Goa, Bihar, and Uttar Pradesh, respectively.

Fig. 4 presents a pair of scatter plots of rural and urban energy cost burdens (state level means, by round) against electricity access, calculated as a percentage of all households who have electricity access, by state and by round. Similarly, Fig. 5 shows these same relationships for LPG access. Since access is positively correlated with non-energy expenditure, the lack of a clear relationship in Fig. 4 and in Fig. 5 between energy cost burden and non-energy expenditure is consistent with the hypothesis that access and energy expenditures go hand-in-hand.

We now present the regression results to test the above explanations for variation in household energy expenditures: household income and access to modern fuels. The unit of analysis in all the below regressions is a household and all models include state-round fixed effects.

Table 3 presents six different models using the full sample of households. Non-energy expenditures have negative and statistically significant association with energy expenditures in all models. However, the coefficient is quite small and remains small when LPG and electricity access, as well as control variables, are taken into account. This is consistent with the energy cost burden thesis: households that incur higher non-energy expenditures spend less on energy related purchases. A positive and statistically significant coefficient would have provided some support for the income hypothesis, but the data actually falsify the hypotheses. In theoretical terms, rising incomes do not result in increased energy expenditure. The energy cost burden decreases with economic growth, because energy expenditures remain stable while the consumption of other goods increases.

On the other hand, LPG and electricity access have a consistent positive and statistically significant coefficient, even after controlling for household size, age/gender of household head, land ownership and fuel prices (Models 2–6). The large and statistically significant effects of LPG and electricity access do not change with the inclusion of price information. These results suggest that greater access to modern fuels has a strong positive association with energy expenditures.

Tables 4 and 5 present similar models when the population is restricted to urban and rural households, respectively. As in the case of the full sample models in Table 3, both LPG and electricity access have a positive and consistently significant coefficient across both urban and rural populations. This means that the positive relationship between energy expenditures and the provision of modern fuel access holds true in both urban and rural areas of the country.

LPG and electricity access as a function of non-energy expenditures

In conducting our analysis, it is important to consider the possibility that higher household incomes cause increased access to modern fuels (Foley, 1992; Ekholm et al., 2010). This association would complicate our analysis, as it would be difficult to evaluate the relative importance of incomes as opposed to access. We guard against this possibility by examining whether there is a strong positive relationship between modern energy access and household income. In Tables 6 and 7, we report results from regressions that use household non-energy expenditures to predict access to modern fuels. This test shows that this proxy for household incomes is not a good predictor of access to modern fuels: although the coefficient is positive in the full sample, it is tiny; in the urban and rural samples, the coefficient is actually negative. Therefore, the effect of access to modern fuels cannot be attributed to an indirect effect of household incomes. Access to modern fuels thus mostly depends on other factors, such as government policy, infrastructure, and markets.

Discussion

Our data analysis of the energy cost burden in India has revealed significant rural–urban differences, variation across states, and an increased burden over time. Notably, the increased energy cost burden has mostly fallen on states in central India. In contrast, the poorer states

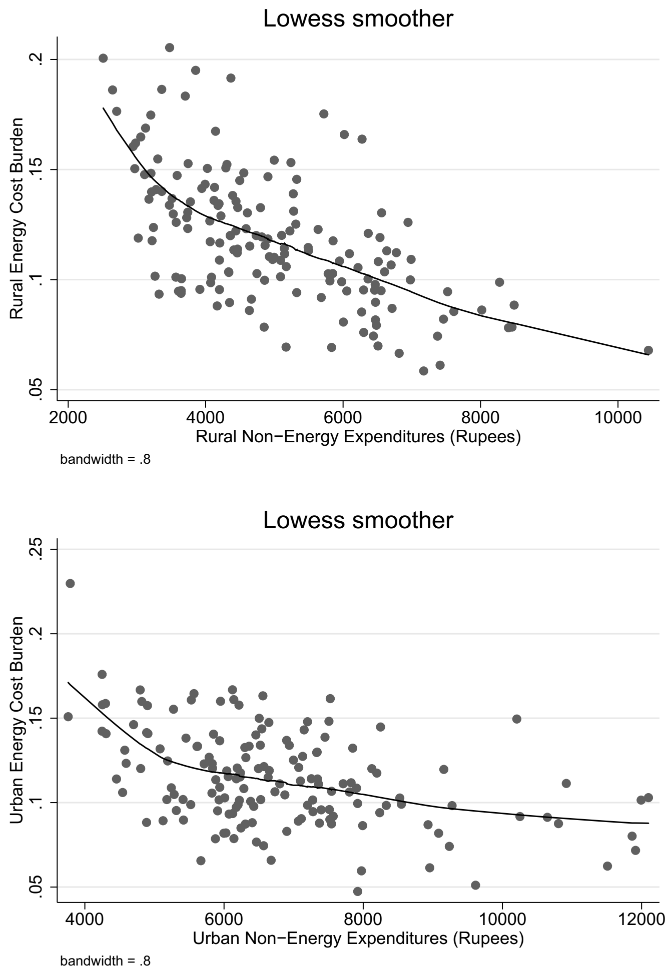

Fig. 3. Rural and urban non-energy household expenditure (*x*-axis) and energy cost burdens (*y*-axis). Each observation is the mean of household expenditures (in rupees) and of the energy cost burden for a state in a given round ($N = 163$). A locally weighted scatterplot smoother is fitted to the data.

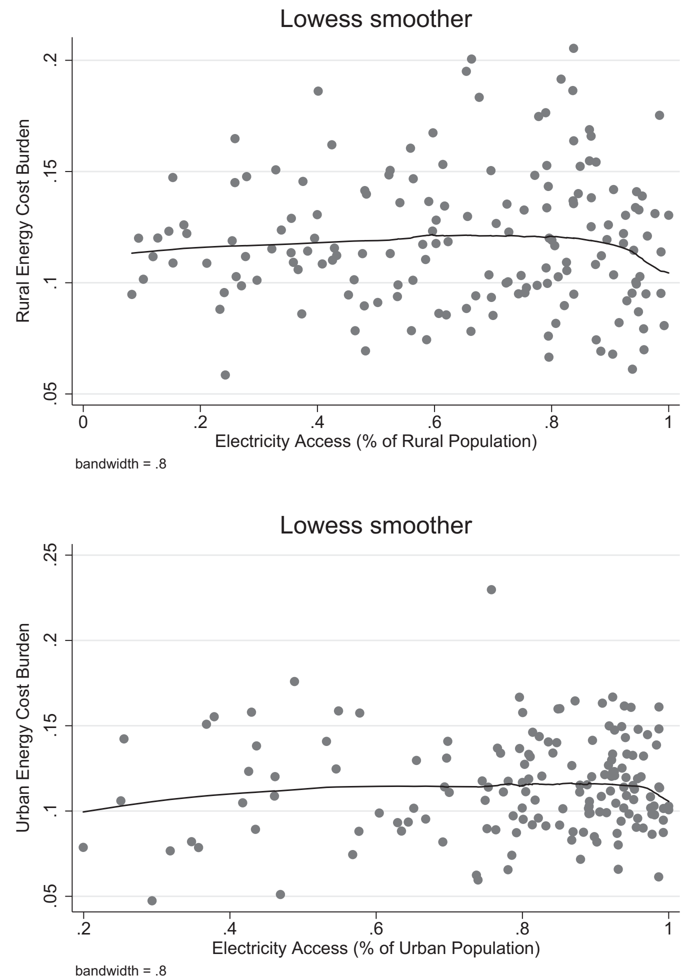

Fig. 4. Rural and urban energy cost burdens (*y*-axis) and electricity access as proportion of population (*x*-axis). Each observation is the state mean (rural or urban) in a given round ($N = 163$). A locally weighted scatterplot smoother is fitted to the data.

of the northern Hindi heartland and the wealthy states of the south seem to have mostly avoided the larger increases. These descriptive findings raise the question of what factors explain this variation. While there has been much empirical research on variation in access to modern energy in India and elsewhere (Revelle, 1976; Pachauri and Spreng, 2004; Pachauri et al., 2004; Narasimha Rao and Sudhakara Reddy, 2007; Khandker et al., 2012; Cheng and Urpelainen, 2014), the role of energy affordability has largely been ignored. Studies that do address it, such as Winkler et al. (2011), do not test hypotheses on explanations for variation across regions and over time.

The regression analysis, in turn, quantifies the association between access to modern fuels and increased energy expenditures within Indian states over three decades. While there is a correlation between household level non-energy expenditures and energy expenditures, it is actually negative and small. When non-energy expenditures increase, energy expenditures (very slightly) decrease. In contrast, the large substantive coefficient of access to LPG and electricity is robust to variation in statistical specification. While energy poverty and income poverty go together across households, especially among the poorest (Khandker et al., 2012), growing household incomes across Indian states over time have not produced large increases in household energy expenditure. In this sense, our results are consistent with the association between energy and non-energy expenditure reported by Khandker et al. (2012). What is new about our analysis is that we show the same logic holds across India over a period of almost three decades, and holds across the very different economic conditions of rural and urban areas.

In the Indian context, one possible reason why the association between energy and non-energy expenditure over time within states has not been stronger is that the energy cost burden was high to begin with. If the typical household was already allocating more than 10% of its expenditure to energy both in rural and urban areas in 1987, it is not altogether surprising that rising incomes would lead households to emphasize other goods and services. Energy expenditures remain stable while non-energy expenditures grow because the energy expenditures were, relatively speaking, high to begin with. In practice, this means that, as long as accessibility of modern fuels remains constant, Indian energy planners may expect expenditures to remain stable. Conversely, improved access to modern fuels will prompt increases in energy expenditure, a fact that is useful for policy formulation over the coming decades.

The findings also highlight fundamental differences between industrialized and developing countries in terms of energy poverty. In industrialized countries, "fuel poverty" in the form of inability to pay for heat, electricity, and transportation fuel is a major policy issue that has been studied extensively (Fankhauser and Tepic, 2007; Moore, 2012; Walker and Day, 2012). In developing countries, the lack of access remains the key issue. While some new products, such as solar power, may face challenges of affordability (Riley, 2014), our findings indicate that, in India, the more fundamental constraint is the lack of access. This may change over time as modern fuels become a basic element of

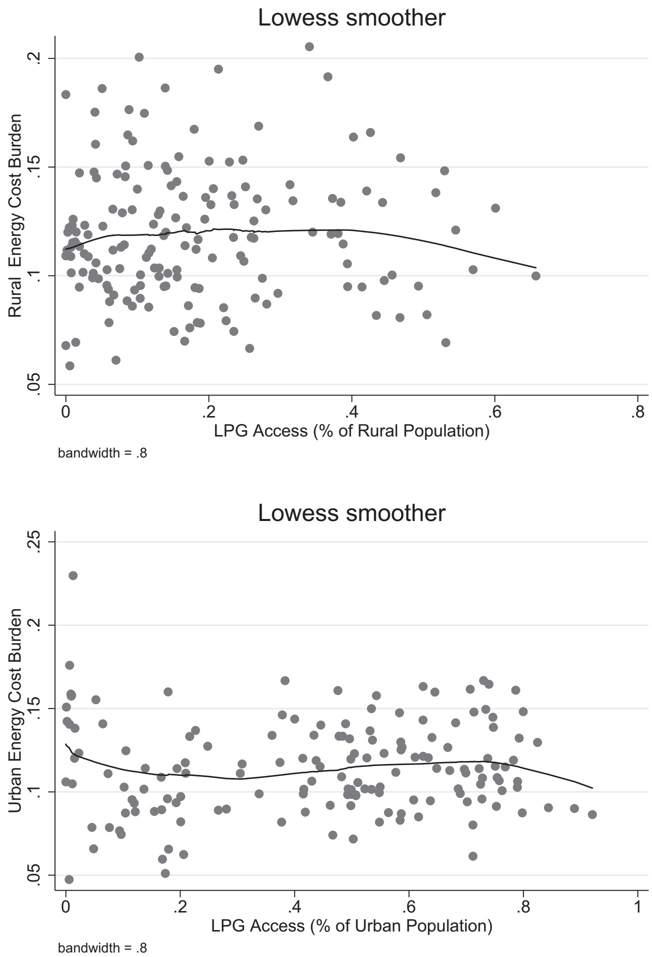

Fig. 5. Rural and urban energy cost burdens (*y*-axis) and LPG access as proportion of population (*x*-axis). Each observation is the state mean (rural or urban) in a given round ($N = 163$). A locally weighted scatterplot smoother is fitted to the data.

every household's consumption bundle, but India has not yet reached this stage. While increases in the energy cost burden may initially appear alarming, in practice they indicate the successful expansion of access to modern fuels, with positive socioeconomic effects (Khandker et al., 2009; Andadari et al., 2014).

Conclusion and policy implications

This article has shown that increased household energy expenditures in India reflect, first and foremost, improved access to modern fuels (LPG for cooking, electricity for lighting and appliances). While variation in household non-energy expenditure is not associated with variation in household energy expenditures, access to modern fuels is strongly correlated with higher levels of spending. This is consistent with the findings that even very poor people are willing to pay for high-quality modern energy. Moreover, it means that the energy cost burden decreases as a household's overall ability to spend improves.

This finding has significant implications for energy policy in India and elsewhere. If total household energy expenditure is not primarily a function of household income, then efforts to increase access to modern fuels can work even in deprived areas. This is encouraging news for countries such as India, where large segments of the society remain without access to modern fuels. If this access were improved through infrastructural development, market creation, and public policy, the poor would gain access to a highly valuable energy service and be willing to pay for it. This money could, in turn, be used to finance further improvements in access. Based on our results, a self-sustaining financial mechanism for improving energy access among the poor is possible.

Another linkage between payments and energy access concerns the possibility that access to modern fuels contributes to local economic dynamism and socioeconomic development. Many studies suggest that household energy access is beneficial to education, health, agricultural productivity, access to information, and small business (World Bank, 2008; Bernard, 2010; Khandker et al., 2013; Samad et al., 2013; Andadari et al., 2014). If households understand these benefits, then the lack of correlation between income and energy expenditure could reflect anticipated future benefits of modern fuels. Since the poorest need economic improvements the most, they may value modern fuels as a profitable investment for the future. This would explain why access to modern fuels, as opposed to income, is the critical explanation for increased household energy expenditures. Where the poor have access to modern fuels, they can improve their quality of life and productivity in the long run.

Accounting for state characteristics with fixed effects, our statistical specifications focus on the relationship between household income, access to modern fuels, and energy spending. Even at the state level, high economic growth over a period of more than two decades is not a predictor of increased energy spending. In contrast, access to modern fuels is. Where government and private efforts to improve LPG and electricity access have succeeded, households have responded by spending

Table 3
Energy consumption for the full sample of households. The dependent variable in these models is the log of energy expenditure based on all households. All models use survey weights and also include state-year (state-round) fixed effects. Robust standard errors are in parenthesis.

	(1)	(2)	(3)	(4)	(5)	(6)
Non-energy expenditure (log)	−0.021***	−0.045***	−0.075***	−0.075***	−0.076***	−0.087***
	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
LPG access (indicator)		0.589***	0.595***	0.595***	0.595***	0.577***
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Elec access (indicator)		0.438***	0.439***	0.439***	0.439***	0.442***
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Household size			0.017***	0.017***	0.017***	0.017***
			(0.001)	(0.001)	(0.001)	(0.001)
HH age				0.000**	0.000*	−0.000
				(0.000)	(0.000)	(0.000)
Female HH (indicator)					−0.016***	−0.016***
					(0.006)	(0.006)
Land (log)						0.003***
						(0.001)
Observations	576,480	576,480	576,480	576,160	576,160	495,481
r^2	0.101	0.318	0.320	0.320	0.320	0.321

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 4
Energy consumption for urban households. The dependent variable in these models is the log of energy expenditure based on all urban households. All models use survey weights and also include state-year (state-round) fixed effects. Robust standard errors are in parenthesis.

	(1)	(2)	(3)	(4)	(5)	(6)
Non-energy expenditure (log)	−0.072***	−0.047***	−0.065***	−0.066***	−0.066***	−0.071***
	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
LPG access (indicator)		0.699***	0.698***	0.698***	0.698***	0.708***
		(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
Elec access (indicator)		0.467***	0.466***	0.466***	0.466***	0.452***
		(0.009)	(0.009)	(0.009)	(0.009)	(0.012)
Household size			0.013***	0.012***	0.012***	0.012***
			(0.001)	(0.001)	(0.001)	(0.002)
HH Age				0.000**	0.000**	0.000*
				(0.000)	(0.000)	(0.000)
Female HH (indicator)					−0.011	−0.008
					(0.009)	(0.010)
Land (log)						0.003
						(0.002)
Observations	219,091	219,091	219,091	218,998	218,998	160,029
r^2	0.085	0.351	0.352	0.352	0.352	0.356

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 5
Energy consumption for rural households. The dependent variable in these models is the log of energy expenditure based on all rural households. All models use survey weights and also include state-year (state-round) fixed effects. Robust standard errors are in parenthesis.

	(1)	(2)	(3)	(4)	(5)	(6)
Non-energy expenditure (log)	−0.063***	−0.051***	−0.093***	−0.093***	−0.094***	−0.104***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)
LPG access (indicator)		0.489***	0.487***	0.487***	0.487***	0.479***
		(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Elec access (indicator)		0.457***	0.456***	0.456***	0.456***	0.458***
		(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Household size			0.020***	0.020***	0.020***	0.020***
			(0.001)	(0.001)	(0.001)	(0.001)
HH age				0.000**	0.000*	−0.000
				(0.000)	(0.000)	(0.000)
Female HH (indicator)					−0.022***	−0.022***
					(0.007)	(0.008)
Land (log)						0.004***
						(0.001)
Observations	357,389	357,389	357,389	357,162	357,162	335,452
r^2	0.133	0.290	0.293	0.293	0.293	0.297

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

more money on energy. For policymakers, the implication is that, if the central government were to increase investments in rural electrification and cooking fuel programs, then Indian households would gain access to valuable energy services and spend money on them. While it is clearly true that wealthy states generally have better access to modern fuels than poor states, there is considerable variation across states at any level of income. This variation creates opportunities for policy interventions.

The ability and willingness to pay among the poor suggests that commercial approaches to improved energy access should be considered.

Table 6
LPG Access (full, urban and rural). The dependent variable in these models is a binary indicator for LPG access at the household level. All models use survey weights and also include state-year (state-round) fixed effects. Robust standard errors are in parenthesis.

	(1)	(2)	(3)
Non-energy expenditure (log)	0.031***		
	(0.001)		
Non-energy expenditure (log)		−0.026***	
		(0.003)	
Non-energy expenditure (log)			−0.011***
			(0.001)
Observations	576,480	219,091	357,389
r^2	0.098	0.128*	0.097**

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 7
Electricity access (full, urban and rural). The dependent variable in these models is a binary indicator for LPG access at the household level. All models use survey weights and also include state-year (state-round) fixed effects. Robust standard errors are in parenthesis.

	(1)	(2)	(3)
Non-energy expenditure (log)	0.013***		
	(0.001)		
Non-energy expenditure (log)		−0.014***	
		(0.002)	
Non-energy expenditure (log)			−0.014***
			(0.002)
Observations	576,480	219,091	357,389
r^2	0.240	0.141*	0.278**

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Financial viability is widely considered a major barrier to commercial energy access programs in developing countries (Rao et al., 2009; Mainali and Silveira, 2011; Palit and Chaurey, 2011; Chaurey et al., 2012) and international organizations such as the International Finance Corporation are keen to create effective and profitable business models for improved energy services (International Finance Corporation, 2012). Our findings suggest that such commercial opportunities exist. Investments in improved infrastructure and markets can pay for themselves because households are ready to spend significant sums of money on modern fuels. Especially for the growing sector of off-grid electrification, which relies heavily on private capital (Bairiganjan et al., 2010; Tenenbaum et al., 2014), this commercial angle is important, as our results offer ample reason for optimism.

For policymakers and analysts in India, our study highlights the need to critically evaluate the use of household energy spending, and even household energy prices, as indicators of affordability. According to our findings, high levels of energy spending reflect greater energy access. In a microeconomic sense, many households would be willing to significantly increase their energy spending, but the lack of access to modern fuels prevents them from doing so. Households seem to be willing to leave the health, opportunity, and security costs of using firewood, dung cakes, and kerosene behind, but they will be unable to do so without improved access. This is a situation that calls for new policy interventions and innovative approaches to improve access.

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