Energy 76 (2014) 306–317

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Fuel stacking in India: Changes in the cooking and lighting mix, 1987–2010☆

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ARTICLE INFO

Article history:
Received 26 May 2014
Received in revised form
3 August 2014
Accepted 4 August 2014
Available online 3 September 2014

Keywords:
India
Fuel stacking
Lighting
Cooking
Household surveys
Energy access

ABSTRACT

In the developing world, households often stack multiple fuels. In the case of India, they use both kerosene and electricity for lighting while cooking with both LPG (liquefied petroleum gas) and traditional biomass. Existing scholarship on fuel stacking largely relies on small surveys and does not investigate change over time. We leverage the nationally representative NSS (National Sample Survey) of India in 1987 and 2010, finding that fuel stacking is decreasing in lighting, as people substitute electricity for kerosene, but increasing in cooking, as LPG does not replace traditional biomass. We also exploit a two-stage statistical model to analyze individual household's decision of fuel stacking. The most important finding is that, while a high household income reduces fuel stacking for lighting, it no longer does so in 2010 for cooking. The main policy implication of the study is that much more aggressive efforts are needed to deal with problems associated with biofuels, such as indoor air pollution, than to induce the switch from kerosene to electricity. The statistical model offers a considerable improvement over existing alternatives in the literature on household energy access.

1. Introduction

The choices of cooking and lighting fuel in developing countries are crucial for reasons of poverty alleviation, public health, and environmental protection [2,17,20,27]. However, the study of fuel consumption in developing countries has proven to be difficult. The empirical investigation of fuel stacking in developing countries is demanding because comprehensive data on fuel consumption are often incomplete or flawed in many developing countries [9]. As Ref. [14] write, the traditional "energy ladder model," whereby households switch linearly to cleaner fuels from traditional biofuels as their wealth increases relative to the fuel price [11], has limited explanatory power. Households often use multiple cooking and lighting fuels. Explaining such "fuel stacking" is essential for theory building and policy development [1,15].

While Ref. [14] proposed the idea of fuel stacking more than a decade ago, however, we still do not know how common it is, whether it applies to cooking and lighting equally, and what kinds of households engage in it. The results from a recent review of several studies indicate that nationally representative studies remain rare [24], and available ones [7,22] largely focus on cross-sectional survey in a single year. Since the household economic model of fuel choice also posits that education and household size, which jointly determine the opportunity cost of consuming a particular fuel, determine whether a household will combine solid and non-solid fuels in their energy consumption portfolio [9], many empirical studies have employed multivariate regression analysis. Unfortunately, this technique often yields biased estimates, as existing research tends to overlook the selection bias in the adoption of modern fuel before uncovering the determinants of fuel stacking.

The primary goal of this article is to describe and explain changing patterns of lighting and cooking fuel patterns in India, 1987–2010. To extend current scholarship on fuel stacking while mitigating the problem of limited evidence, we leverage an exceptionally large and nationally representative dataset, the NSS (National Sample Survey), from India.[1] As one of the largest nationwide randomized socio-economic surveys in the world [5], the NSS dataset provides an accurate picture of household consumption expenditures, including detailed measures of fuel expenditures, and relevant socio-economic characteristics. In each

☆ We thank Preeti Varathan and Michael Graham Smith for research assistance. We also thank the Columbia Program on Indian Economic Policies for access to data.
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[1] For a general description, see http://mospi.nic.in/. Accessed December 1, 2013.

http://dx.doi.org/10.1016/j.energy.2014.08.023
0360-5442/

round, the survey inquires the amount of fuels consumed by each household in terms of quantity and price (rupees). For this study, we have processed and analyzed the raw data for the major survey rounds for the years 1987 (43rd round) and 2010 (66th round). We describe and analyze patterns of fuel stacking in these two years. The difference of 23 years offers a precious opportunity to characterize major trends in the Indian household fuel consumption. These trends shed light on the nature of and trends in energy transition from the world's largest democracy, where every third household was without electricity in 2010 and more than seven out of ten households used traditional biomass for cooking, according to the 2010 round of our data.

Another goal of this article is to understand what types of households engage in fuel stacking. To determine the factors that predict fuel stacking, we next propose a new analytical approach based on a two-stage statistical model along the lines of [8]. In the first stage, the household decides on the inclusion of a modern fuel, be it electricity (lighting) or LPG (cooking), in the mix. In the second stage, the household decides whether or not to continue using the primary traditional alternative, which is either kerosene (lighting) or biomass (cooking). Our statistical model accounts for the interdependence between these two decisions to avoid biased estimates. The two-stage approach sheds new light on the determinants of fuel stacking, adding to the large body of literature on the topic so far.

2. Fuel stacking in India: an overview

To delineate major trends in fuel stacking, we must first reduce the dimensionality of the problem by identifying the most important cooking and lighting fuels in India. While Indian households use a dozen of different fuels, it turns out that spotting the major cooking and lighting fuels is ultimately simple. We reduce the dimensionality of the lighting fuel choice to that of kerosene and electricity, while focusing on LPG (liquefied petroleum gas) and biomass on the cooking part.

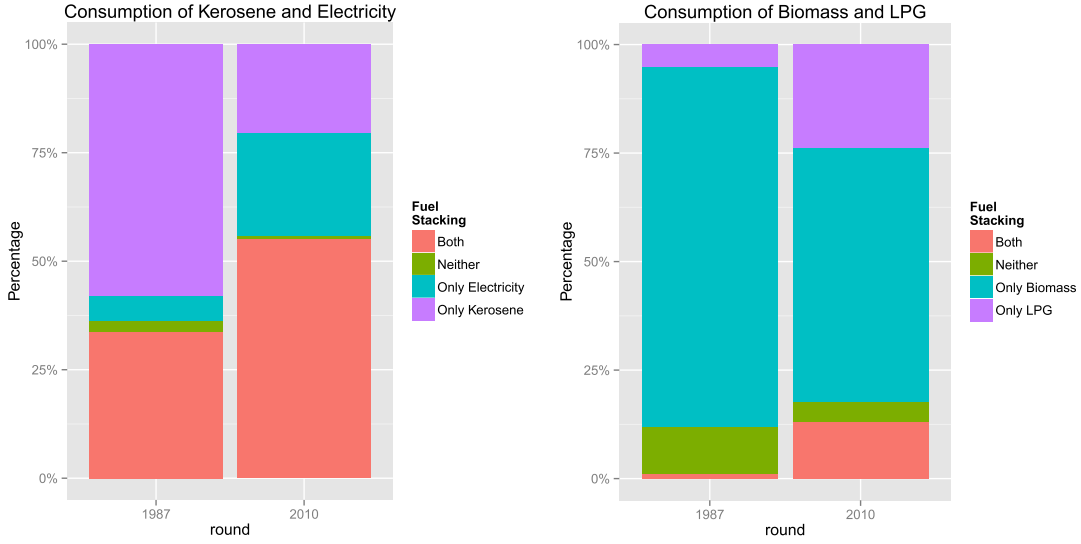
In the case of lighting, the vast majority of Indian households choose between kerosene and electricity. The central and state governments have for decades offered generous subsidies for kerosene purchased through public distribution shops [19] and efforts to electrify Indian households have made steady, if slow, progress since the nation's independence in 1947 [12]. However, the reliability and quality of grid electricity remains poor in many areas [23]. In both years of our data, fewer than five per cent of all households use neither electricity nor kerosene. Since fewer than one per cent of households have no lighting at all, the share of other lighting solutions is, as of today, negligible.

For cooking, the main options in India are biomass and LPG. Most households can choose from the different varieties of biomass fuels, firewood, chips, and dung cakes. As a developing country with hundreds of millions living in poverty, traditional biomass is by far the most common cooking solution [21,25]. Due to government subsidies and ease of use, LPG has recently emerged as a credible alternative especially in rural areas. Other cooking solutions, such as electricity and kerosene, are much less common. In the 1987 round of our data, only slightly more than one out of ten Indian households used neither kerosene nor LPG, and by 2010 this proportion has decreased to below five per cent.

2.1. Overall patterns

The overall patterns of fuel stacking are shown for the first (1987) and last (2010) year of our data in Fig. 1. With respect of lighting, the share of households that only consume kerosene substantially decreases in 2010 while the size of those stacking both of kerosene and electricity increases from 33.9% to 55.2%. Regarding cooking energy, it has become much less common that households only use biomass fuels; the share decreases sharply from 82.8% to 58.6%. Meanwhile, the singular use of LPG rises from 5.2% to approximately 24%. Therefore, it appears that household fuel consumption in India has become more or less modernized from 1987 to 2010. While in 2010 biomass remains the most popular cooking energy, it is still a remarkable progress given that only 6.2% of Indian households use LPG in 1987.

The patterns illustrated by Fig. 1 clearly do not completely accord with the expectation from the energy ladder model. In particular, although the relative rarity of biomass-LPG stacking



(a) Kerosene-Electricity Stacking (b) LPG-Biomass Stacking

Fig. 1. Fuel stacking, 1987 and 2010.