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Fuel choices in rural Maharashtra

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ABSTRACT

We report on and analyze the results of an energy use survey in two tribal villages in rural Maharashtra, India. Though there is significant heterogeneity between the effects of the variables in the two villages there are some robust results. We find modest evidence for the 'energy ladder' hypothesis and that use of higher quality energy sources reduces total energy use, *ceteris paribus*. Income elasticities of fuel use are small. Additionally, we demonstrate that household size, stove ownership, and season influence energy choices. However, the effects of improved stoves are small and not consistent across the villages.

1. Introduction

An increasingly large share of global energy use and carbon emissions are accounted for by developing countries, yet the unique features of energy use in the developing world are often not accounted for adequately in international analyses [1,2]. This is particularly true of the use of traditional biomass, which many global models and studies simply ignore. Globally, 2.7 billion people still rely on traditional biomass as their main source of energy for cooking and heating and 1.3 billion people do not have access to electricity. The majority of these people live in sub-Saharan Africa and South Asia [3]. Where electricity is available in rural areas, supply is often intermittent and/or unreliable. The absence of efficient energy options limits the development scope of households [1] and has implications for the local and global environment, as well as the health of those who prepare meals due to indoor air pollution [4–7].

In India, much of the country's modern energy infrastructure is focused on urban centers, which dominate energy use [8]. Rural energy choices are constrained not only by low incomes, but also by thin markets for commercial fuels and equipment. Often, local availability constrains energy use more than either household budget limitations or energy prices [9]. Moreover, cooking accounts for the majority of rural residential energy consumption [10]. With limited resources and access to alternatives, households effectively rely on biomass to supply their most important energy service.

Effective public policy in developing countries also requires analysis of the factors that affect energy demand in the developing world [9]. Though data is now more available than in the past [10], there is still a need to better understand the factors determining energy use in the rural context. In this

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paper, we examine the factors affecting fuel choices and total energy use of households in two villages in Maharashtra state using a primary data set collected by the first author.

Economic theory suggests that "households consume more of the same goods and shift towards higher quality goods as household income increases" [11] and this applies to energy services too. Higher quality fuels are those that provide more economic value per joule of energy content by being converted more efficiently, being more flexible or convenient to use, and by producing less pollution [12]. We would expect that lower income households would be more willing to tolerate the inconvenience and pollution caused by using lower quality fuels to produce energy services. So as household income increases, we would expect households to gradually ascend an "energy ladder" by consuming higher quality fuels and more total energy [9]. Many studies [13–17] have concluded that such an energy ladder exists. However, many more recent studies often find a more ambiguous picture where multiple fuels are used simultaneously with "fuel-stacking" as modern fuels are added to the use of traditional fuels [18–20] or that there is reluctance to move up the ladder [21]. Gupta and Köhlin [22] test the energy ladder hypothesis in India by estimating regressions for the individual demands for fuelwood, coal, kerosene, and liquid petroleum gas (LPG) in Kolkata. They determine that wood, coal, and kerosene act as inferior fuels, while LPG is normal. This implies that as incomes rise, households in Kolkata switch from less efficient fuels to more efficient ones. Reddy [23] researched energy choices for households in Bangalore employing a series of binomial logit models to evaluate the choice between energy pairs. His results suggest that households ascend an energy ladder and that income and some socio-demographic variables are important determinants of energy demand. More recently, Farsi et al. [9] applied an ordered probit model to cooking fuel choices in urban households. Their results indicated that a lack of sufficient income is one of the main factors constraining households. Additionally, several social and demographic factors, including the education and gender of the head of the household, were also found to be important. Other relevant studies for India include Gundimeda and Köhlin [24], discussed below, Heltberg et al. [25] who study total energy consumption, consisting of wood, dung and crop residues in four Rajasthani villages, Köhlin and Amacher [26] who model fuelwood collection in Orissa, World Bank [27] who employ a multinomial logit model to represent household fuel choice for both rural and urban households, Khandker et al. [10] who analyze a large national survey for both rural and urban households, and Pandey and Chaubal [28] who analyze rural households from another national survey. Together, these studies tepidly support the 'energy ladder' hypothesis for India.

Nevertheless, it is interesting to note that many estimated income elasticities of low quality fuels are actually insignificant or even positive [29–32]. This suggests that for many rural households, wood, crop residues, and dung may actually represent normal goods. Hosier and Dowd [13] concede that the energy ladder may not be applicable to all households. In fact, cultural and social preferences may be equally as important as economic ones [9]. Khandker et al. [10] find that even total energy use is not responsive to increased income in the lower half of the income distribution in a large sample of households in rural India.

Obviously, prices are a major determinant of energy use, though as is well known, energy demand is very inelastic [33] and many studies find that prices have a limited effect on fuel choice (e.g. Ref. [34]). Substitution between fuels due to changes in relative prices may also not be so easy in the short run [33,35]. However, Gundimeda and Köhlin [24] found Marshallian (uncompensated) own price elasticities ranging from −0.59 to −1.05 for various fuels in rural India, which is more elastic than is typical for fuels, and (compensated) cross-price elasticities as high as 0.843 for the effect of a rise in the price of LPG on demand for fuelwood in low income rural households. In common with some other rural Indian studies (e.g. Ref. [25]), we did not obtain price data from our field study and energy use was dominated by self-collected firewood. In any case, with data collected from two neighboring villages over the course of a year, price variation was probably limited.

More efficient energy conversion technologies, such as improved stoves and electricity, can reduce energy use [33,36]. There is mixed evidence, however, as to whether technological change actually reduces demand [25,29,37–39]. There are many factors that may reduce or even eliminate any efficiency gained through better technology. For example, stoves may be in disrepair, operated improperly, used sparingly, designed with features other than efficiency in mind, or cause households to consume more energy through the rebound effect [39–41]. Jeuland and Pattanayak [42] carry out a Monte Carlo simulation cost-benefit model that shows that the private net benefits of improved cooking stoves will sometimes be negative, and in many instances highly so. Hanna et al. [41] found that a large share of the 2600 households that received free improved stoves in a randomized control trial failed to maintain them properly so that usage declined significantly after the first year of the trial. Andrianzen [40] found that the iron frames in half the stoves distributed in a region of the Peruvian Andes had failed within five years of distribution, which was among the reasons why many households had stopped using the improved stoves.

Besides the traditional energy choice determinants of price, income, and substitutes, the importance of contextual factors is well documented in the literature [29,32,43]. Household characteristics, including number of members, gender composition, and education, are all associated with 'fuel switching' [21]. Similarly, cultural characteristics, such as religion or caste, can have a pronounced influence on energy use [18]. Fuel characteristics other than price may also play a role in household decision-making, including: ease of use, availability, and pollution generation [18]. Finally, spatial and temporal characteristics, such as geographic location and season, affect household practices.

The model we develop in this paper tests the importance of the various factors described above on energy use and fuel choice in two tribal villages in Maharashtra State, India. The remainder of the paper is organized as follows. First we describe the location in India where our data were collected followed by the design of the survey in section three, the statistical model in section four, and results and analysis in section five. The final section of the paper presents a discussion and conclusions.