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Rural Household Preferences for Cooking Fuels in Developing Countries : A Microeconomic Analysis

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ABSTRACT

Over the years the Energy Ladder Hypothesis has been losing its popularity as a generally accepted one. Several studies pertaining to rural household choice for cooking fuels conducted throughout the globe have disproved its applicability claiming that the observed behaviour among the households of the developing economies conforms to fuel stacking rather than fuel switching as postulated by the energy model. On the basis of certain restrictive assumptions, the paper provides a graphical illustration of the general inferences drawn by a few such studies bringing them to a common platform. As a measure for alleviating energy poverty, the paper prescribes free education as a major policy vehicle which, if administered in conjunction with other remedial measures like provision of subsidized modern fuels and extension of electricity access to rural areas, could be effective in promoting clean energy sources among the masses to meet a significant proportion of their energy demands.

Keywords: Rural household, Energy Ladder, Fuel Switching, Fuel Stacking

Introduction

The term "energy" is intricately linked to every aspect of economic life. It is the fundamental engine that drives industrialization, fosters economic growth and if used judiciously, serves equally well in meeting commercial and domestic needs. However, in the developing world such a criterion is rarely met and the rural masses are denied access to efficient energy carriers They mostly rely upon traditional fuels (eg., fuelwood, dung and crop residue) for cooking, constrained by their low income levels. These fuels are generally collected by women and children — a time consuming activity which details children from attending their schools and women from pursuing other productive works. Animal dung, in particular, is a vital input to agriculture, but its use as a cooking fuel constrains its availability for farming purposes (Heltberg, 2004; Mekonnen & Kohlin, 2008).

Moreover, incomplete combustion of biomass fuels in poorly functioning stoves often leads to the emission of toxic gases and particulate matters which may have serious health implications. Such negative consequences associated with solid biomass fuel use claimed the attention of several researchers and environmentalists to probe into the prospects of improving the economic status of rural households so as to enable them enjoy the fruits of clean modern fuels. The present study intends to throw a pragmatic view on the rural household pattern of fuel choice and examine their responses to changes in fuel price and income, drawing on the findings of the prevailing literature.

The Energy Ladder Hypothesis

The energy ladder model casts the picture of an imaginary ladder each rung of which corresponds to a specific energy carrier. At a particular point in time each household is assumed to stand on a single rung, thereby, choosing one out of a myriad of fuels arranged before it in an increasing order of technological sophistication. The lowest rung of the ladder relates to animal dung and crop waste while the top-most rung corresponds to electricity (as indicated in Fig. 1).

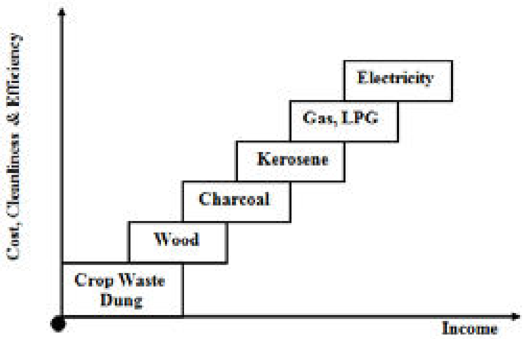

Fig. 1 : Schematic Representation of the Energy Ladder Model Source : Holdren and Smith (2000)

With economic prosperity, brought about either by an increase in money income or a fall in fuel price, the household ascends the energy ladder reaching for more and more sophisticated and efficient energy carriers (Hosier & Dowd, 1987). The model envisions the process of fuel switching in three distinct phases : The first phase displays a universal reliance on biomass fuels, viz., animal dung, crop residue and fuelwood. The second phase is characterized by a switch-over to transitional fuels (eg., charcoal and kerosene) in response to higher incomes and urbanization. In the third phase the household moves to cleaner modern fuels like LPG, natural gas or electricity, for cooking.

Criticism Of The Energy Ladder Model

The applicability of the energy ladder model has, however, been questioned on several grounds. Barnes and Floor (1996) and Leach (1992) opine that the model leaves little room for multiple fuel use. Rather, it conceives the inter-fuel transition as a linear process. Atanassov (2010) argue that fuel choice is determined by a multitude of factors and not by income alone as emphasized by the energy model. According to Masera, Saatkamp, and Kammen (2000) fuel switching is a bidirectional process and is determined by economic, social and cultural factors. Further, as has been pointed out by Heltberg (2004), the energy ladder model runs the risk of implying that a move-up to a better quality fuel is accompanied by a simultaneous move away from the fuels used hitherto. Walking a step ahead along this line, if we partition the fuels into two broad categories, viz., polluting solid fuels (formed by subsuming charcoal within the periphery of traditional fuels that originally comprised dung, crop residue and fuelwood) and cleaner non-solid fuels (including modern fuels as well as kerosene), the energy ladder hypothesis could be led to imply that with an improvement in economic status, the household eventually replaces the solid fuels with the non-solid fuels supposing them to be perfect substitutes. In practice, however, uptake of a better fuel does not necessarily displace the lower-quality fuels (Heltberg, 2004). World-wide evidences on fuel use in developing countries reiterate the fact that households often maintain a portfolio of cooking fuels that span both the upper and lower rungs of the energy ladder, as directed by their budgets, preferences and needs (Mekonnen & Kohlin, 2008). In other words, they believe in fuel stacking (i.e., multiple fuel use) rather than fuel switching to which the energy ladder model alludes. This is evident from the fact that in Vietnam 52% of the rural households mostly use a combination of wood and straw for cooking, 16% of the rural households and 26% of the urban households in Guatemala use a mixture of firewood and LPG while 34% of the rural households in South Africa rely upon firewood and kerosene for cooking (Heltberg, 2004). Similar observations were made in case of rural India by Joon, Chandra, and Bhattacharya (2009). The fact remains that, apart from the factors like accessibility and affordability of modern fuels, household choices are also governed by the cultures and traditions indigenous to the region as well as by the taste imbuing attributes of certain biomass fuels (specifically fuelwood) to cooked meals. Hence, even if the households are able to afford modern fuels, they continue to rely upon traditional fuels, at least in part, to light their fires. As noted by Jiang and O' Neill (2004) from a cross-sectional data set on China, an absolute fall in biomass use could occur only if income increased substantially. Nonetheless, there is no denying the fact, that an increase in money income of the households may cause a reduction in the use of solid fuels. The reason is that with increase in affluence of a household, the traditional fuels come to be regarded as inferior energy carriers from the standpoint of efficiency. Moreover, increased income allows for higher education which awakens the households towards the detrimental impacts of indoor air pollution caused by the combustion of solid fuels.

Modeling The Household Dynamics Of Fuel Use

The household choices for fuel can be diagnosed by using the analytical tools of the theory of consumer behaviour : Let us consider a household which derives utility from a vector of n commodities denoted by q. Since it is difficult for households to make choices from among a huge number of alternatives, it is assumed, following Sadoulet and de Janvry (1995), that the commodities are clustered into several broad groups, each consisting of items displaying similar characteristics, namely, food, fuel and non-food-non-fuel (Gebreegziabher, Oskam, & Bayou, 2010). Accordingly, the commodity vector, q, is partitioned into three sub-vectors viz., qA, qf, qo. The budgeting is then supposed to be done in two steps : In the first step the household allocates its total income to each broad group. In the second step the money reserved for each group is allocated among its constituent items – a process which is termed as step-wise budgeting. Further, we assume that the proportion of income spent on each broad group of items remains unchanged even in case of a rise in money income of the household and that the utility functions are group-wise separable so that,

$$U = f(U(q_A) + U(q_f) + U(q_o))$$

where, U denotes the total utility derived by the household from the consumption of all items collectively and U(qA), U(qf), U(qo) denote the utilities derived from the consumption of individual group of items, viz., food, fuel and non-food-non-fuel respectively. It should be noted that, here separability implies that the marginal rate of substitution (MRS) between any two variables within the same group are unaffected by quantities of variables outside the group (Henderson & Quandt, 1980). Further, in the presence of separability in wants, the optimal values of the choice variables obtained by considering a two-step budgeting are same as the optimal values obtained in case of a single-step budgeting (Sadoulet & de Janvry, 1995) where the over-all utility function is maximized subject to the aggregate budget constraint. Thus, the determination of optimal choices for the items of each group in case of a step-wise budgeting can be regarded as a maximization problem of its own (Gebreegziabher et al., 2010). Since we are interested specifically in determining the optimal choice of cooking fuels, we consider the maximization of the sub-utility function corresponding to the fuel group only, i.e., we consider the second step of the budgeting process assuming that the first step of the process has already been made and a specific amount of money has been kept in reserve for fuel purchase by the household (without entering into the details as to how the budget corresponding to each broad category had been determined).

To facilitate a graphical exposition of the household choice for fuels (which is our ultimate aim) we consider two composite fuels, viz., “traditional” and “modern”, denoted by qt and qm, respectively. The “traditional” fuel is a composite combination of polluting solid fuels such as, animal dung, crop residue, fuelwood and charcoal and the “modern” fuel is a composite of cleaner non-solid fuels like kerosene, LPG, natural gas and electricity. Accordingly, the fuel sub-utility function can be re-written as :

U(qf) = V(qt, qm) and the relevant fuel budget constraint is,

$$M_f = p_t q_t + p_m q_m$$

where, Mf stands for the amount of money allocated to fuel purchase, pt refers to price of the composite “traditional” fuel and pm refers to price of the composite “modern” fuel. The maximization problem can, thus, be stated mathematically as under :

Max V(qt, qm)

Subject to : $M_f = p_t q_t + p_m q_m$

To depict this problem in a graph let us consider quantity of “modern” fuel along the horizontal axis and quantity of “traditional” fuel along the vertical axis (see Fig. 2).

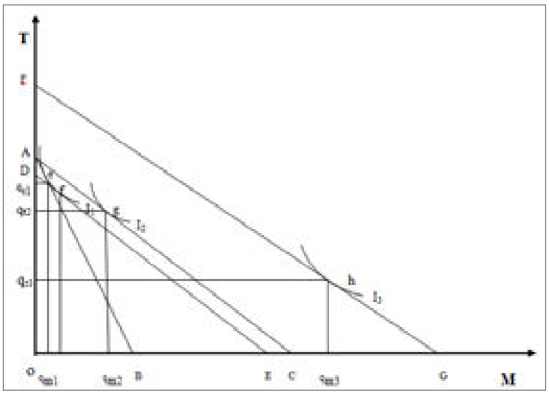

Fig. 2 : Household Equilibrium Consumption of Cooking Fuels

Initially price of the “modern” fuel was quite high so that the household could afford only a nominal quantity (Oqm1) of the fuel and had to meet the rest of its energy needs by using Oqt1 units of the polluting “traditional” fuel, as determined by the point of tangency between the indifference curve I1 and the fuel budget line AB. With a fall in price of the “modern” fuel the fuel budget line moves to AC and the economic status of the household improves, so that it is now able to increase the purchase of that fuel to Oqm2 units, reducing the use of the "traditional" fuel to Oqt2 units. The movement from point "e" to "g" can be split into two separate effects : a substitution effect indicated by the movement from point "e" to "f" along the indifference curve I1 and an income effect shown by the movement from point "f" to "g", taking the household to a higher indifference curve I2. As is evident from the figure, the household consumption of the "traditional" fuel decreases not only due to the substitution effect but also due to income effect as the household now considers the fuel to be inferior. However, the household does not replace the "traditional" fuel entirely by the "modern" fuel as implied by the energy ladder model (discussed earlier), i.e., it considers the "traditional" fuel and the "modern" fuel to be imperfect substitutes. This is due to the fact that, since the household's educational level is at a bare minimum, it is not adequately aware of the negative health impacts associated with traditional fuel use. Rather, it attaches more importance to the prevalent traditions and cultural practices and hence, continues using the fuel together with the "modern" fuel. Even though a fall in price of the "modern" fuel leads to a rise in real income, it is not sufficient enough to allow for an increase in the educational level of the household.

Policy Prescriptions

The pattern of energy use by the rural households of developing countries calls for immediate action to arouse the awareness of the rural masses regarding the impending health risks of traditional fuel use by way of imparting free education as far as practicable. This would also open up new venues for earning and enable the poor to avail of a greater quantity of efficient modern fuels, thereby, tempting them to reduce the use of traditional fuels to a level so low as would be commensurate with the proper living standards. Reverting to Fig. 2, we find such a situation where provision of free education might increase the earning potential of the household. As assumed in the foregoing analysis, an increase in money income would initiate a proportionate rise in fuel budget, shifting the fuel budget line parallely to the right to FG and enabling the household to direct more funds towards the purchase of the "modern" fuel (so that its purchase rises to Oqm3) and reduce the use of the "inferior traditional" fuel to Oqt3 — a level even smaller than that of previous level, Oqt2 — at the new relative prices. In this case, the reduction in the use of the "traditional" fuel may be attributed to the combined effect of two factors : (i) a rise in fuel budget following a rise in money income and (ii) an increase in awareness of the household, effected through free education, regarding the potential health hazards of traditional fuel use. The movement from point "g" to "h" (on the indifference curve I3) may, thus, be termed as the "budget-cum-awareness" effect.

In addition to the above, campaigns should be made against the harmful impacts of solid fuel use. Measures may also be taken to provide certain modern fuels like kerosene and LPG at subsidized rates and access to electricity may be extended to the rural areas to promote job creation via the growth of new industries that would enhance the living standards of the masses.

Conclusions

The paper makes a theoretical investigation regarding the relevance of the Energy Ladder Model in the context of developing countries. Partitioning the energy carries under two broad heads, viz., "traditional" fuel and "modern" fuel, it graphically demonstrates that the actual phenomenon observed in case of such economies is that of fuel stacking, rather than fuel switching as postulated by the Energy Ladder Hypothesis. In other words, it shows that with an increase in economic well-being, effected through an increase in income or a drop in fuel price, the rural households tend to use a mixture of traditional and modern fuels instead of relying exclusively on the latter, since they are typically tied to their customs and traditions relating to the former. In view of these circumstances, the study advances certain policy options that would enlighten the rural poor regarding the perils of solid fuel use so that they are able to do away with their prejudices and at least minimize the use of the fuel, if not altogether avoidable. It also prescribes measures for easing the access to modern fuels which could

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