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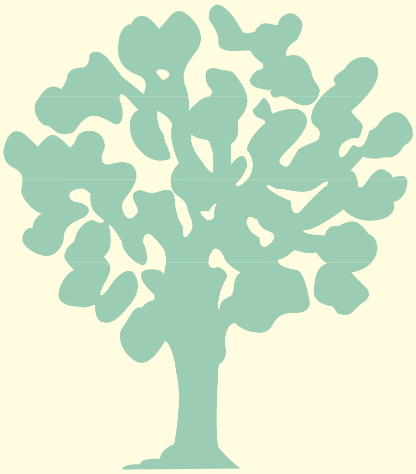
Determinants of Fuelwood Use in Rural Orissa: Implications for Energy Transition

Arabinda Mishra



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Abstract

This study examines household behaviour related to fuelwood collection and use. The focus is on identifying the behavioral transition of fuelwood-using households from collection to purchase. The study examines the theory linking households' labour allocation decisions to choice of fuel and models household decision using a three-stage least squares probit specification. Household fuelwood choice (purchase/collection) is predicted based on an endogenously determined wage income that depends on the opportunity cost of fuelwood collection. Expectedly, economic ability and availability of fuel alternatives are found to have significant positive marginal effects on household choice for fuelwood purchases. There is also the possibility that at very high levels of income, and in the absence of alternatives to choose from, households may revert back to collecting fuelwood using either their own labour or hired workers. The policy implication of a possible reverse switch is that improvements in economic ability alone may not be sufficient to bring about the energy transition in rural areas; there may be a need to continue with price subsidies on kerosene and LPG and at the same time create effective institutions for conserving forest commons.

Keywords: Fuelwood collection and use, Household labour allocation, Energy transition, Reverse switch, India

Determinants of Fuelwood Use in Rural Orissa: Implications for Energy Transition

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1. Introduction

Rural households living in close proximity to the forest in India use fuelwood not only for domestic purposes, but its collection and sale is a major livelihood activity in deprived regions. Estimates from the 55th Round National Sample Survey (NSSO, 2001) covering a country-wide sample of 71,385 rural households, reveal that 75% of these households use firewood and chips as the primary energy source for cooking and lighting, and close to 90% of households use one or the other form of solid biomass-based fuels for meeting domestic energy needs.

By all accounts, the energy transition from biomass to clean fuel types (kerosene, electricity, LPG) has been extremely slow in rural India (Pachauri and Jiang, 2008; TERI, 2008). The extensive use of traditional biomass-based fuels by rural households also is a cause for concern because of health-related impacts associated with these energy sources (WHO, 2002). Respiratory illness, a leading cause of child mortality (under-5 years) in rural India, and cataracts, particularly among women, are linked to smoke emissions from household fuelwood use (UNDP/ESMAP, 2003).

Besides the health impacts of fuelwood use, another policy concern is deforestation from fuelwood collection. Baland et al (2006), for instance, report that forest degradation in the Indian mid-Himalayas is driven primarily by collection of fuelwood and fodder by the residents of neighbouring villages.

The typical policy approach to the use of fuelwood and other biomass-based fuels is to induce an 'energy switch' to relatively cleaner fuels like kerosene, LPG, electricity, natural gas and biogas. In India, government interventions for this purpose have principally focused on providing universal price subsidies on the kerosene and LPG supplied by state-owned oil companies.[1] However, since 1997, the government has reduced price subsidies on kerosene and LPG.[2] This change in policy is supported by a number of studies that provide evidence of the regressive nature of such subsidies and the problem of huge leakages (Gangopadhyay et al, 2004). Apart

[1] The subsidized kerosene is distributed through a Public Distribution System (PDS) and has quantity restrictions for households that vary from state to state, between rural and urban areas, and across household categories in terms of nil, single or double LPG connection. The subsidized LPG is sold through the dealer network of the public sector oil companies and carries no quantity restrictions. While private sector participation is allowed in the kerosene and LPG markets, there are no subsidies on the supplies from this sector.

[2] The target year for bringing down subsidies to 33.3% on kerosene and 15% on LPG was 2002. In 2002-03, total subsidy to consumer on kerosene distributed through the Public Distribution System (PDS) was Rs 4.14 per litre, (with a 25% subsidy on the market price of Rs 16 per litre). The unsubsidized market price of LPG per cylinder is Rs 470 but is sold at Rs 130.27 per cylinder (which is a subsidy of around 28%)) (price data from UNDP/ESMAP, 2003 and subsidy data from TERI, 2008). The latest subsidy estimates for the year 2006-07 are even higher: Rs 15.99 per litre for kerosene and Rs 178.66 per cylinder of domestic LPG (TERI, 2008).

from inefficiencies in implementation, the failure of price subsidies to bring about the energy transition in rural India has been linked to freely/cheaply available fuelwood and the low opportunity cost of labour (UNDP/ESMAP, 2003).

This study examines the premise that households which are already participating in the fuelwood market as buyers have the highest probability of switching to clean fuels. The few studies that examine household choice between collecting fuelwood and purchasing it from the market commonly use the theory of opportunity cost of labour.[3] In rural economies with significant forest-based livelihood activities, household-level labour allocation decisions are inextricably linked to energy-related choices. As long as the opportunity cost of labour is greater than the return from fuelwood collection from forest, a household will prefer to purchase fuelwood from the market (or, go for alternative sources of fuel) rather than allocate its own labour to collect wood.

Policy interventions that have been linked to the above theory include labour market improvements in the non-farm sector (Bluffstone, 1995),[4] and interventions for improving farm productivity in the vicinity of forests (Gunatilake and Chakravorty, 2003).[5]

This study aims to contribute to the empirical literature on factors that determine household behaviour related to fuelwood collection and use. Of particular interest is identifying the motivation behind the observed behavioral transition of fuelwood-using households from collection to purchase. The study site is characterized by open access forests, upstream-downstream differences, fragmented fuelwood and labour markets, and extreme inelasticity in supply of alternative fuel types. The analytical methods take into account that rural households typically derive income from multiple sources.

The organization of the rest of the paper is as follows: Section 2 presents a conceptual framework along with an optimization model that links fuelwood related behaviour to labour allocation decisions; section 3 describes the study area and sampling strategy; section 4 analyzes patterns in the survey data related to fuelwood collection and use; section 5 presents the econometric results of household participation in the fuelwood market; section 6 provides the Willingness to Pay (WTP) estimates for alternative fuel; and section 7 concludes the paper.

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3 The theory behind this is that in the presence of labour market imperfections (which is typical for rural economies in developing countries), the opportunity cost of labour would diverge from the market wage rate and the production decisions of rural agricultural households become non-separable from their consumption decisions (Sadoulet and de Janvry, 1995). Different approaches have been used in the applied studies that deal with the estimation of opportunity cost of family labour. The study by Amacher et al (1996), for instance, derives the instrumental variable estimates of the marginal product of labour from a household production function specification. Bardhan et al (2001) on the other hand relate true labour costs to household and village characteristics through a constrained maximization of the household's utility function.

4 Bluffstone's (1995) simulation analysis point to the possibility of an energy transition occurring for fuelwood users in rural Nepal on account of large increases in the off-farm wages for labour that serve to increase the opportunity cost of fuelwood collection from the forest. Again, in the context of fuelwood collection in rural Nepal, Bardhan *et al* (2001) report the significant moderating effect on household deforesting behaviour caused by the growth of non-agricultural activities and availability of commercial fuel substitutes.

5 Allowing for legislative measures to prevent forest land conversion, Gunatilake and Chakravorty (2003) reach the conclusion that higher output prices, lower input prices and improved production technology in agriculture, all serving to improve farm profits in vicinity areas of the forest, would increase the opportunity cost of extraction and thereby result in reduced labour allocations to forestry at the household level.

2. Household Fuel Choice: Theory and Evidence

The early theorizing on household fuel choice is based on the ‘energy ladder’ model and the associated notion of ‘fuel switching’. In the simpler version of the model, as explained in Leach (1992), household fuel choice is mostly income-determined and passes through a linear 3-stage switching process that initially involves solid biomass fuels, but with increasing economic prosperity leads finally to LPG and electricity, usually via a transition phase involving kerosene, coal and charcoal. Household behaviour can be explained in terms of the wealth and substitution effects of increases in household income (Bardhan *et al*, 2001). For household choice related to fuelwood, both these effects are hypothesized to be negative as fuelwood is assumed to be an inferior good. Current empirical evidence, suggests a more complicated process at work than the simple linearized version of the energy ladder model. First, the phenomenon of ‘fuel stacking’ suggests that richer rural households opt for a mix of modern and traditional fuel types to meet larger energy requirements (UNDP/ESMAP 2003). Similar evidence exists for other parts of the world (Heltberg, 2005; Masera *et al*, 2000).

Second, there is evidence to suggest that determinants other than household income may be as important, if not more, in explaining fuel choices by the rural users. Narain et al (2008) found that fuelwood use and dependence (defined as its contribution to the total ‘permanent income’ of households) increases with forest biomass availability irrespective of income levels. Veld *et al* (2006), on the other hand, provide evidence that fuelwood shortages in rural areas (because of forest degradation) tend to induce households to switch in the short-run to either using fuelwood from private trees or to agricultural waste, and in the long-run to alter the mix of private trees in their own land in favour of trees that can supply fuelwood. Hyde and Kohlin’s (2000) find validating evidence from round the world on the positive links between household fuelwood collections and the availability as well as accessibility of forest stock. The distance to the forest is generally taken to be an indicator of its physical access by households and this, in turn, is expected to be inversely linked to fuelwood collections.[6]

The demand-side determinants of fuelwood use – other than income – include household size, education, occupation and social group (e.g. caste category)[7]. Size of a household, other things remaining the same, is directly related to its energy requirements and a bigger household would be expected to have a higher level of fuelwood consumption[8]. While ritualistic preferences among the upper caste households may be expected to cause higher consumption of fuelwood, the greater exposure to forces of modernization for households with superior social status would possibly induce a switchover to alternatives of fuelwood as the sources of energy. The level of education is again a strong indicator of social achievement and is expected to discourage fuelwood consumption. A TERI (2001) survey of primary energy usage in Jalore district of Rajasthan (India) found that rural households switching from fuelwood to LPG typically had members employed in occupations that required them to travel frequently to the nearby urban centre (thereby allowing for refilling of cylinders) and were more aware of the fuel and its use.

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6 In their study of rural Malawian households, Brouwer *et al* (1997) found evidence of a switching behaviour (from fuelwood to lower quality twigs) that occurred when distance to the source increased beyond a point and resulted in households using more twigs (therefore, lesser fuelwood) collected from a shorter distance.

7 User characteristics are likely to be strongly interdependent. In rural India the richer households quite often belong to the more privileged caste groups and have higher levels of educational attainment.

8 Smaller households may also have a tendency to economize on fuelwood use because of a lesser availability of household labour that may be allocated for fuelwood collection (Brouwer *et al* 1997).

Bandyopadhyay and Shyamsundar (2004) using NSS data (54^{th} round) found the link between fuelwood consumption and household participation in community forestry to be significantly positive. Outside of India, to cite one relevant study, Amacher *et al* (1996) found significant behavioural differences between collecting and purchasing households in Nepal's *tarai* and mid-hills with respect to predictive variables such as, market prices, labour opportunities, the availability of substitutes, and access to the forest. This suggests the possibility of exogenous changes in the predictive variables inducing a 'switching behaviour' among fuelwood user households in which purchasing households may switch back to collecting or vice versa.

The 'multiple factors – multiple fuels' model accepts clean fuel as a merit good and aims at energy transition from solid biomass to LPG and electricity. Fuel stacking suggests that traditional subsidy-based policy interventions are unlikely to succeed in completely phasing out fuelwood and other traditional fuel types so long as the opportunity costs of collecting/producing such fuels are significantly lower than the prices of their cleaner substitutes.

The structural link between household labour allocation decisions and fuelwood-related behaviour may be explained in terms of the framework presented in Figure-1. Rural households may generate income from multiple sources and accordingly allocate the total labour with which they are endowed at any given time (middle box in the figure). Rural asset holdings such as the land cultivated and livestock define the own labour requirement of households and it is the surplus labour, which seeks to access other income-generating opportunities in the farm and non-farm sectors. Exogenously determined changes in such opportunities (uppermost box in the figure) would arguably result in shifts in the supply patterns of rural household labour. Thus, for example, a policy induced exogenous increase in minimum wages for rural labour may be expected to induce households to allocate more of their surplus labour to wage-earning activities and reduce labour hours devoted to collection. The bottom panel of the figure has household income as the endogenous predictor and includes other possible demand- and supply-side determinants of a household's labour allocation decision. The feedback effect of a switch on self collection by households is illustrated by the dashed line.

An optimization model

An optimization model is built following on linkages identified in Figure-1. We take the case of the representative household, whose utility (U) is determined by energy use (E), leisure (l_l), and a composite of all other goods consumed (M). Preferences of the household are conditioned by a set of household (Z_h) and village characteristics (V_i). For meeting its energy needs, the household faces the choice of consuming fuelwood either collected from the forest using own labour (x_f) or purchased from the market (x_m). It is further possible that the household sells part of the fuelwood collected from the forest. Thus, to account for all possibilities, the household's consumption of fuelwood is represented by the sum total of the fraction of total collections that is kept for own consumption (αx_f ; $0 \leq \alpha \leq 1$) and amount purchased (x_m). The fraction α is assumed to be exogenously determined by factors such as household size and caste category. Alternatives to fuelwood are not considered because of their absence for the overwhelming majority of households in the study area.

The total labour time available to the household (T) has a part (A) that complements the productive assets owned by it, such as land and livestock, and is assumed to be exogenously determined. The household faces the choice of engaging the surplus labour, wholly or in part, either in the labor market (l_m), in which case it will be earning wage income, or in collection of x_f from the forest (l_f). A third choice for the household would be to avail leisure (l_l) that directly contributes to its welfare. The market valuation of household labour time would be based on a given exogenous wage rate (w), whereas for the non-participant labour engaged in fuelwood collection activity or leisure, the household makes its own valuation based on the opportunity cost or shadow wage rate (w*).

We set up the household model below:

$$U = U(E, l_l, M; Z_h, V_i) \quad (1)$$

$$E = E(\alpha x_f + x_m), \text{ where } 0<\alpha<1, \text{ and } x_f, \; x_m \geq 0 \quad (2)$$

$$x_f = F(l_f; Z_h, V_i) \quad (3)$$

$$T - A = l_f + l_m + l_l \textit{ where } l_f, \; l_m, l_l \geq 0 \quad (4)$$

$$p_f x_m + M = w l_m + p_f (1 - \acute{a}) x_f + Y \quad (5)$$

such that

$$\partial Y/\partial E > 0, \; \partial Y/\partial l_l > 0, \; \partial Y/\partial M > 0, \; \partial Y/\partial l_m < 0 \quad (6)$$

$$\partial F/\partial l_f > 0, \; \partial^2 F/\partial l_f^2 < 0 \quad (7)$$

Equation (5) gives the income constraint for household expenditure on fuelwood purchased and the composite good (price of M is assumed to be unity as the numeraire). The right hand side of the equation gives the income from different sources – wl_m is the wage earnings, $p_f(1-\alpha)x_f$ is the income from fuelwood sales, and Y captures the income from all exogenous sources. Introducing the non-negativity constraints (2) in the model allows us to derive the switching condition for households facing the choice between purchasing fuelwood and collecting it from the forest. The production function for the collected variety of fuelwood is given in (3) and the assumptions given in (7) ensure its neoclassical curvature. Equation (4) gives the decomposition of the productive labour time available with the household and non-negativity constraints on the three surplus labour components are introduced to derive the conditions of their optimal allocation among different activities. Finally, the partial slopes in (6) show that while the household experiences greater utility from increased consumption and leisure, more of wage labour is inherently dissatisfying.

We now set up a constrained optimization exercise as a Lagrange function (L):

$$L = U(E(\acute{a}\, F(l_f; Z_h, V_i) + x_m), (T - A - l_f - l_m), M) + \lambda[p_f x_m + M - w l_m - p_f (1 - \alpha) F(l_f; Z_h, V_i) - Y] \quad (8)$$

From the Kuhn-Tucker maximization conditions for the choice variables, l_f, l_m and x_m, we have:

$$\partial L/\partial l_f = (\partial U/\partial l_f) \quad \lambda p_f (1-\alpha)(\partial F/\partial l_f) \leq 0 \quad (9)$$

$$\text{or, } \partial L/\partial l_f = (\partial U/\partial l_f) - \lambda(1-\alpha) w^* \leq 0 \quad (9.1)$$

$$\partial L/\partial l_m = -(\partial U/\partial l_m) - \lambda w \leq 0 \quad (10)$$

$$\partial L/\partial l_m = \partial Y/\partial x_m + \lambda p_f \leq 0 \quad (11)$$

The opportunity cost of labour w* in (9.1) is the value of marginal product (VMP) of household labour used for collecting fuelwood from the forest. The multiplier λ is Lagrangean multiplier. From (9.2) and (10), using the respective complementarity conditions, we get the switching condition for a household choosing between collection and labour market participation for its surplus labour as:

$$(\partial U/\partial l_f)/(\partial U/\partial l_m) = -[(1-\alpha)w^*]/w \qquad (12)$$

Assuming that marginal utilities on the left hand side of the above equation and "α" are unchanged, when there is an exogenous rise in "w", it would imply that the shadow wage (w*) will also increase by the same extent. Also, an exogenous change "w" if matched by a similar change in $(\partial U/\partial l_m)$ leaves the equilibrium ratio unchanged.

Similarly, equations (9.1) and (11) give us the switching condition:

$$(\partial U/\partial l_f)/(\partial U/\partial x_m) = -[(1-\alpha)w^*]/p_f \qquad (13)$$

Using both the optimization conditions (12) and (13), we can establish the interdependence between household labour allocation decisions and fuelwood-related behaviour as follows:

$$-(\partial U/\partial l_f)/[(1-\alpha)w^*] = (\partial U/\partial l_m)/w = (\partial U/\partial x_m)/p_f \qquad (14)$$

Under conditions of optimality, Equation (14) simultaneously and proportionately equates the marginal disutility of fuelwood collection and the marginal disutility of wage labour with the marginal utility of fuelwood purchases.

The implicit relationship among the choice variables, l_f, l_m and x_m in equation (14) provides the basis for the empirical estimation that follows in Section 5. Simultaneity in household decisions is modelled using a three-stage least squares (3-SLS) estimation of a probit specification. Given a set of household and village level characteristics, household fuelwood choice (purchase/collection) is predicted using an endogenously determined wage income variable (wl_m) that, in turn, depends on the opportunity cost of fuelwood collection. But before we begin our econometric exercise we will briefly describe our study area and mode of data collection.

3. Study Area and Sample

According to recent estimates 47.2% of the Orissa's population belongs to the Below Poverty Line (BPL) category, which makes the state the poorest in the country. The incidence of poverty is still greater, 64%, among the largely forest-dependent indigenous tribal communities, which account for nearly a fourth of the state's population (GoI, 2002).

There is considerable variation among the 30 districts of Orissa in terms of development status, the social composition of the population and the extent of forest cover. The present study is based on data from 20 selected villages spread across 2 districts (administrative units) of Orissa. The study area is a tropical deciduous forest with sal (*Shorea robusta*), the predominant species, along with bamboo and kusum (*Schleichera oleosa*).

The two selected districts, Gajapati and Ganjam, differ drastically from each other on all the three parameters (see Table 1) but are adjacent to each other and share a common link in the form of an irrigation project, namely, the Harabhangi Irrigation Project on the river by the same name. The downstream irrigated area of the Harabhangi Project marks the beginning of the coastal plains in the Ganjam district. In sharp contrast, the upstream dam and its catchment area falls in the Gajapati district and is a hilly region. While Ganjam is the more developed district in socio-economic terms, Gajapati has a significantly larger tribal population as well as a greater extent of forest cover.

This study is based on household level primary data collected in both the upstream and downstream areas of the Harabhangi river. A total of 600 households (300 in each district) were surveyed in the region during the first half of 2003. Since the dam project is the common factor linking both areas, the sample was based on the type of project impact. In the upstream dam area there are two categories of project-affected households —'displaced' and those 'not displaced but who have lost land'. In the downstream irrigated area there are the households 'who have benefited from irrigation' and those 'who have lost land but have *not* benefited from irrigation'. In both areas the unaffected households were treated as the "control" category. A total of 13 upstream and 7 downstream villages were surveyed. In contrast to the equal sample sizes for the different project based categories in the upstream area (100 sample households from each category), the number of sample households varies for the three different categories in the downstream area (project affected: 117; project benefited: 96; and control: 87). The reason for this difference is that while in the upstream area each category could be identified with an entire settlement, the same was not possible in the downstream area.[9]

4. Data

Socio-economic characteristics

The difference in the basic characteristics of the upstream and downstream regions can be observed in the descriptive statistics (see Table-2). The one-way ANOVA tests of the mean estimates indicate that there are significant differences between the two regions in terms of the social stratification, quality of life, household size and gender composition, education and asset holding. The average rank estimates derived for the variable on social composition ('soclgrp') indicate that households belonging to the less privileged scheduled tribe (ST) and scheduled caste (SC) categories are dominant in the upstream sample. Economically, and also in terms of other measures of social advancement, the downstream households appear to be better placed. The mean estimate of the education variable ('yrsedn') obtained for the downstream region is more than double the corresponding upstream estimate. Similarly, the overall quality of life enjoyed by the households, indicated by the type of house variable ('house_type'), is higher for the downstream sample as compared to its estimate obtained for the upstream counterpart. While, on an average, households in the downstream region have the advantage of a greater cultivable land area ('tlndcult'), those located in the hilly upstream area have a larger livestock holding ('lvstksiz'). The upstream households, on an average, have a greater endowment of female labour ('sxratio') whereas, in terms of the average household size ('hhsadeq'), the mean estimates are higher for the downstream households.

The downstream sample has a higher average gross annual household income ('annhhinc'). The standard deviation in income for the downstream area's income distribution is also considerably higher compared to its upstream counterpart, which is suggestive of greater income inequality in

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9 Downstream villages contained households belonging to all the three categories and while selecting the households the only limit placed related to the sample size for the region as a whole.

the downstream region. In fact, the Gini coefficient measure[10] of inequality based on the survey data relating to gross annual income of the sample households, is 0.41 and 0.48 for the upstream and downstream area, respectively.

Fuelwood collection and fuel use

Table-2 also shows that, average monthly fuelwood collection ('fuelw_coll') for the upstream sample households is nearly double the amount collected by the downstream households. However, the monthly consumption of fuelwood ('fuelw_cons') is on an average almost the same for both regions. In both the regions, the forest is the dominant source of fuelwood and only a few households have access to other-than-forest sources ('source_d).

Households of the downstream irrigated area have to travel nearly twice as far to reach the forest ('distf_vill'), compared to the upstream area. The indicators relating to the *intensity* of collection activity at the household level, are significantly lower for the downstream households[11], Very few households go in groups to the forest for collection and use of mechanized means of transport in the activity is also limited.[12] The 'lbtmcoll_unit' variable used in the present study refers to the average number of hours spent by household members, individually or in a group, to gather a *bhari* of fuelwood from the forest and includes the time spent in journeying to the forest and back. The higher mean estimate of this variable in case of the downstream is possibly an indicator of the greater constraints (distance being one of them) on fuelwood availability in that region. A relatively greater preference among the downstream households for group collection and the use of wheeled means of transport thus appears to be a coping strategy involving intensive extraction. An overwhelming majority (98.2%) of the households use fuelwood for cooking, either as the single energy source or in combination with other traditional and modern fuel types (Table-3). The use of clean fuels like kerosene, electricity and LPG in cooking is limited to only 9% of the sample . On the other hand, while over 90% of the sampled households use kerosene for the purpose of lighting, only about 12% are found to have electricity connection. From among the 137 sample households using more than one fuel type for cooking (Table-4), only 43 households (i.e. 31.4%) use at least one clean fuel type from the set of electricity, kerosene and LPG – these are the households that have partially switched over to cleaner fuel options. While higher income levels are associated with multiple fuel use, they do not necessarily choose a clean fuel.

Fuelwood using rural households are categorized into four groups: (a) the 'seller' households for whom fuelwood collection is a livelihood activity; (b) the 'collector' households that collect fuelwood only for own consumption and whose domestic energy requirements could be entirely met from the forest source; (c) households that feel the need for purchasing some amount of fuelwood from the market in addition to the collection from the forest for own consumption; and (d) the purely 'buyer' households. Table-5 presents some of the relevant descriptive statistics for the four fuelwood user categories. A majority of households (42%) collect fuelwood (either

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10 The Gini coefficient, G , is estimated using the formula: $G = \frac{2}{N\overline{Y}} Cov(Y, R)$ where N is the number of observations, $\overline{Y}$ the average of the 'annhhinc' series , and R is the corresponding series of ranks (Pyatt et al, 1980).

11 The total number of its adult members going to the forest for fuelwood collection ('memb_coll') and the average number of collection days per month ('colldays').

12 This is inferred from the low values of the two variables linked to the *mode* of fuelwood collection – 'grpcoll_d' and 'mdtrnsp_d' in both the regions.

from the forest or from other-than-forest sources, or both) solely for own consumption while 39.3% were sellers. Only 3.3% households both collect and purchase fuelwood, whereas 15.3% are pure buyers.

Compared to the collecting households (categories 'a' and 'b'), the purchasing households (categories 'c' and 'd') on average, belong to the more socially-privileged upper-caste groups, have larger number of members, are more educated and economically better-off, cultivate larger landholdings, located at a greater distance from the forest, and consume more fuelwood per head per year.

Household income composition and fuelwood consumption

The source-wise composition of income is expected to change as rural households move up the economic ladder. Table-6 presents mean estimates of the annual household income for the income quintiles within three of the four fuelwood user categories mentioned above — the 'seller', the 'collector', and the pure 'buyer'. The fourth category (those who buy as well as collect fuelwood) is not considered because of its very small proportion in the sample.

'Forest income' (consisting of income from sale of fuelwood and other non-timber forest produce) becomes less important as income increases but the high income households in the 'seller' and 'collector' categories still show healthy contributions to household income from the forest source. This is to be expected because fuelwood collection and collection of other NTFPs (non-timber forest products) would be complementary activities for household labour allocated to the forest. The declining share of forest income is accompanied by an increasing share of the wage component in the 'sellers' category. In fact, between the first and the fifth quintile of this user category, the decline in the relative share of forest income (about 30%) is almost exactly matched by an increase in the share of wage earnings. Allowing for the larger size of the high-income households in general, it is possible that a greater labour endowment enables households to access wage earning opportunities in the non-forest sectors as well.

The relative share of non-farm income (consisting of income from salaried jobs, petty business, sale of household crafts and remittances) is greater, higher the income quintile, irrespective of the user category. However, in case of households belonging to the 'buyer' category, this component increases dramatically across the quintile groups to 81% in total income. Differences in educational attainment of households appear to be an important factor in this case. Compared to the other two user categories, the buyer households have significantly higher levels of educational attainment, and between the first and fifth quintile within the category itself the difference with respect to this variable is quite large.

Figure-2 presents the quintile-wise estimates of fuelwood consumption for the different household categories. The upward slopes of the graphs suggest a dominant positive income effect; the slope of the graph for the 'buyer' category is especially striking in this regard.

5. A Probit Model of Fuelwood Purchase

The patterns identified from simple descriptive statistics suggest that the source-wise composition of income may have an important bearing on energy choices of rural households. To examine this possibility, we use a two-stage least squares (2SLS) probit model that has the source-wise income components (or their proxies) as the predictors from which ‘wage_inc’ is endogenously determined. The ‘nonwage_inc’ component is mostly in the form of salary remittances and earnings from the sale of artisan products, and is assumed to be an autonomous component. In place of a similar income variable for the farm sector, which would raise additional endogeneity concerns, we include total land cultivated (‘tlndcult’) and livestock size (‘lvstksiz’) variables as asset proxies. The forest income component drops out of the model given its strong correlation with the ‘wage_inc’ variable.

Going by the framework presented in Figure-1 that points to inter-linkages among household labour allocation decisions, the 2SLS model actually turns out to involve a 3SLS estimation procedure. In the first stage we use 2SLS to generate the instrumental variables (IV) estimates of ‘wage_inc’, with ‘lbtmcoll’ as the endogenous regressor in the ‘wage_inc’ equation. The control variables used in the system include a regional dummy, household characteristics (size, gender composition, education, social group), and household- as well as village-level variables related to access of fuel sources (household access to electricity and non-forest sources of fuelwood; village access to forest and LPG). There are no price related variables since there is little variation of fuelwood price within the upstream and downstream regions of the study area, and the charges for the use of electricity and LPG are generally of fixed nature.

The complete system of equations used for estimation is as follows (Table-7 gives the definitions of all the variables used in our system of estimable equations along with the expected signs of the predictor variables):

$$\begin{aligned}\Pr(\text{buyer\_d}=1) = {} & \text{constant}_1 + \beta_1\text{region\_d} + \beta_2\text{distf\_vill} + \beta_3\text{electy\_hh} + \beta_4\text{lpg\_vill} + \beta_5\text{source\_d} \\ & + \beta_6\text{caste\_d} + \beta_7\text{hhsadeq} + \beta_8\text{hhsadeq2} + \beta_9\text{yrsedn} + \beta_{10}\text{tlndcult} + \\ & \beta_{11}\text{tlndcult2} + \beta_{12}\text{lvstksiz} + \beta_{13}\text{wage\_inc} + \beta_{14}\text{wage\_inc2} + \beta_{15}\text{nonwage\_inc} \\ & + \beta_{16}\text{nonwage\_inc2} + \text{error}_1 \qquad (17)\end{aligned}$$

$$\begin{aligned}\text{wage\_inc} = {} & \text{constant}_2 + \gamma_1\text{region\_d} + \gamma_2\text{hhsadeq} + \gamma_3\text{hhsadeq2} + \gamma_4\text{yrsedn} + \gamma_5\text{sxratio} + \gamma_6\text{tlndcult} \\ & + \gamma_7\text{tlndcult2} + \gamma_8\text{lvstksiz} + \gamma_9\text{lbtmcoll} + \text{error}_2 \qquad (18)\end{aligned}$$

$$\begin{aligned}\text{lbtmcoll} = {} & \text{constant}_3 + \mu_1\text{region\_d} + \mu_2\text{hhsadeq} + \mu_3\text{hhsadeq2} + \mu_4\text{yrsedn} + \mu_5\text{sxratio} + \mu_6\text{tlndcult} \\ & + \mu_7\text{tlndcult2} + \mu_8\text{lvstksiz} + \mu_9\text{source\_d} + \mu_{10}\text{distf\_vill} + \mu_{11}\text{caste\_d} + \text{error}_3 \\ & \qquad (19)\end{aligned}$$

Table-8 reports the estimates obtained for both the stages of the IV regression. Majority of the instruments are statistically significant and carry signs as expected. A Hausman endogeneity test, based on the comparison between OLS and IV estimates, rejects the null hypothesis that the difference in coefficient estimates is not systematic [chi2 (9)=17.9; prob>chi2=0.0364] and therefore endogeneity is established in the model.

The test statistics for the probit equation show that out of the 16 predictors, 10 are found to be statistically significant at the 1% level (Table-9). Interestingly, despite the significant differences between the upstream and downstream areas in terms of the overall level of development, households’ decision to participate in the fuelwood market as buyers seems to be motivated by a common set of influences (as judged from the statistically insignificant coefficient estimate of the region dummy, ‘region_d’). Of the four supply-side determinants, only the source dummy (‘source_d’) is statistically insignificant but has the expected negative sign. Similarly, as expected, increased distance to forest and greater access to cleaner fuel substitutes like electricity and LPG have significant positive marginal effects on a household’s decision to opt for purchased fuelwood.

The social status of households (‘caste_d’) is significant implying that the fuelwood-user household of a socially under-privileged caste group is less likely to be a ‘buyer’. On the other hand, education of household members seems to encourage the switch from fuelwood collection to its purchase. Household size (‘hhsadeq’) is also significant, but has non-linear impacts: an increase in the household size by one adult equivalent unit serves to increase the probability of fuelwood collection from the forest by about 4%, but for the larger households there is the indication (from the squared term ‘hhsadeq2’) that collection probabilities start coming down.

The income/asset determinants linked to land cultivated (‘tlndcult’), wage income (‘wage_inc’) and non-wage income (‘nonwage_inc’) show a striking similarity in influence on household choice between collection and purchase. For all these three predictors the coefficient sign of the squared terms changes to negative suggesting that at higher levels of income there are chances of fuelwood-using households to revert back to collection.[13] A possible explanation of this kind of household behaviour is that the richer households with greater energy needs find it more economical to collect fuelwood from open access sources rather than purchase.[14] In other words, beyond a certain economic threshold, the income effect on fuelwood consumption seem to dominate over opportunity cost considerations in the allocation of household labour for fuelwood collection, particularly when the forest is open access and alternatives are either unavailable or insufficiently available. The existence of a dominating income effect on the energy consumption of wealthy rural households needs to be factored into public policy aimed at bringing about an energy transition in villages.

What if the richer households are using hired labour rather than own family labour to collect fuelwood from the forest? Unfortunately our survey data does not capture this possibility. If, however, this were what is happening in the study regions, it would mean that the richer households are still *purchasing* fuelwood indirectly by spending on the wages of hired workers. In such a case, a more effective supply-side intervention is required that eases the fuelwood-purchasing households to make the energy switch.

Another interesting result is the high and statistically significant coefficient estimate of the ‘wage_inc’ variable, which suggests that an incremental increase in a household’s wage earnings raises its chances of switching from collection to fuelwood purchase by 11%. This finding also serves to underline the labour allocation decisions by households implicit in their choice of fuel usage. Again this suggests that, in the absence of alternative income-generating opportunities, supply-side interventions alone would probably fail to wean away asset-poor but labour-surplus rural households from using fuelwood to other clean fuel alternatives.

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13 For the state of Orissa as a whole, NSS (54th Round) data shows that the number of households using fuelwood increases with increase in land ownership. For the highest landowning category in the hilly region of the state, households using fuelwood constitute more than 90% of the total households in that category.

14 We are of course assuming here that there is no supply constraint on fuelwood sold so that the purchase option for households stays valid; otherwise, any increase in demand can only be met by self collection.

6. Expected WTP for Fuelwood from Markets

As per the mean estimates presented for different household categories in Table-5, the pure buying households spend around 6% of their annual income on fuelwood consumption per year[15]. It is quite possible that the buyers themselves are unaware of the cumulative amount they are spending on fuelwood purchase in a year and how this amount compares with what they have to pay if they switch over to using kerosene or LPG, provided the government takes care of the supply-side constraints.

From a policy perspective, it is important to get WTP (willingness to pay) estimates for households participating in the fuelwood market. The survey for the present study was not originally designed as a contingent valuation survey and hence the econometric estimation of households' WTP for marketed fuelwood is not possible. However, we can use the probabilities predicted by the 2SLS probit model along with the survey data on fuelwood consumption to estimate the lower bound that each household would be willing to pay for obtaining fuelwood from the market. The simple formula used for this purpose is:

Expected WTP per member for i^{th} household = (Predicted choice probability for the i^{th} household) x (Per capita annual fuelwood consumption of i^{th} household) x (Market price of fuelwood for the region)

Table-10 presents the expected WTP estimates for different income quintiles belonging to the upstream and downstream regions. While the upstream estimates are negligible, those obtained for the downstream region are fairly significant in absolute terms and clearly linear in relation to household income. For the representative household belonging to the highest downstream income quintile, a per capita WTP estimate of Rs 338 per year translates to a total annual expenditure of about Rs 1500 on fuelwood. This is equivalent to what the household would have spent on five LPG refills. Anecdotal evidence from the field suggests that such a household would require an average of eight refills to satisfy a year's energy need for cooking.

Interestingly, the WTP progressively declines as a percentage of income for downstream households (when the mean per capita estimates are presented as percentages of mean per capita income). This implies that richer households are willing to spend relatively less on fuelwood purchases although we know from Table-6 that fuelwood consumption increases with income. This could be due to the presence of open access forest in the neighnourhood and to a certain extent corroborates our earlier claim of a reverse energy switch among the rural rich.

7. Conclusion

The slow transition from biomass to clean fuel types in India is commonly explained in terms of the higher costs of the latter fuel types along with the lack of an effective supply network in the rural areas. This study examines switching behaviour of households in terms of a shift from collection to market purchases. Economic ability and availability of fuel alternatives have a significant

[15] The UNDP/ESMAP study (2003) found that rural households using purchased wood as primary cooking fuel spend around 5% of total household expenditure on fuelwood. This is higher by a percentage point when compared to what households using LPG as primary cooking fuel spend on LPG in rural India. More recent survey estimates (NSSO, 2007) show that in India, 10% of domestic monthly per capita expenditure is attributed to spending on fuel and light to meet their energy needs.

positive marginal effects on household choice for fuelwood purchases. At the same time, there is the possibility that at very high levels of income, and in the absence of alternatives to choose from, households may revert back to collecting fuelwood using either their own labour or hired workers. The possibility of a reverse switch implies that an improvement in economic conditions alone may not be sufficient to bring about the energy transition in rural areas. Further, continuing with price subsidies on kerosene and LPG on the one hand and creating effective institutions for conserving forest commons may be a desirable policy choice.

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TABLES

Table 1: Socio-economic and forest-cover indicators for the two study districts

Indicators	**Ganjam district**	**Gajapati district**
District geographical area as % of the total geographical area of the state	5.6 (3)	2.5 (17)
Tribal population as % of the total population of the district (2001 census)	3.2	47.9
Percentage of rural poor families to total number of rural families in the district (GoO, 1997)	55.0	61.4
Total Literacy Rate (2001 census)	62.9 (17)	41.7 (26)
District Rank (in descending order) according to Index of Living Condition (GoI, 2002)	11	21
District Rank (in descending order) according to Infrastructure Development Index (GoI, 2002)	6	19
Total forest area (TFA) as % of geographical area (FSI, 2001)	26.7	59.0
Of which (as % of TFA):		
Dense forest	*50.0*	*56.0*
Open forest	*50.0*	*44.0*

Note: Figures in brackets give the ranks(in descending order)among the 30 districts of Orissa

Table 2: Descriptive statistics for the upstream and downstream samples

Variable	Definition	Upstream sample (N=300) mean & S.D.*	Downstream sample (N=300) mean & S.D.*
soclgrp	social group (1=ST; 2=SC; 3=OBC & minorities; 4=general)	**1.7** *(1.0)*	**3.6** *(1.2)*
hhsadeq	household size in adult equivalent terms (number)	**4.9** *(2.0)*	**5.2** *(2.3)*
sxratio	household sex ratio (adult females as % of adult total)	**52.8** *(19.0)*	**47.7** *(15.8)*
yrsedn	total years of education for the household as a whole (years)	**7.0** *(9.9)*	**15.3** *(16.6)*
tlndcult	total land cultivated by household (in acres)	**1.0** *(1.2)*	**1.7** *(1.9)*
lvstksiz	size of livestock holding, measured as the present stock of cows, buffaloes, oxen & bullocks (number)	**3.3** *(4.1)*	**2.8** *(4.4)*
house_type	type of house (1=hut; 2=kutchha; 3=semi-pucca; 4=pucca)	**1.4** *(0.9)*	**2.2** *(1.3)*
annhhinc	gross annual household income (rupees/year)	**15141** *(14432)*	**22332** *(27073)*
fuelw_coll	average monthly fuelwood collection from the forest by a household (bharis/month)	**28.0** *(18.2)*	**15.3** *(18.7)*
fuelw_cons	average monthly fuelwood consumption by a household (bharis/month)	**15.9** *(12.7)*	**15.4** *(12.1)*
source_d	dummy for non-forest sources of fuelwood, such as roadside trees, trees in private landholdings, social forestry projects, etc (other than forest=1, 0 otherwise)	**0.2** *(0.4)*	**0.2** *(0.4)*
distf_vill	distance to forest from village in kms.	**2.4** *(1.4)*	**4.4** *(2.1)*
memb_coll	total number of adult members from a household going to the forest for fuelwood collection (number)	**1.3** *(0.7)*	**0.9** *(0.7)*
colldays	average number of collection days per month per household (days/month)	**18.3** *(7.6)*	**8.7** *(8.2)*
grpcoll_d	dummy for mode of fuelwood collection (0=Individual collection; 1=Collection in a group)	**0.1** *(0.3)*	**0.3** *(0.3)*
mdtrnsp_d	dummy for mode of transport used in fuelwood collection activity (0=Walking; 1=Otherwise)	**0.0** *(0.1)*	**0.2** *(0.3)*
lbtmcoll_unit	labour time spent by household members for collection of one fuelwood bhari in reference period (hours/bhari/reference period)	**2.4** *(1.7)*	**3.3** *(2.8)*

* Standard deviation (S.D.) values given in parentheses

Table 3: Fuel type and use

Fuel type	Number of household users		
	Cooking	Heating	Lighting
Fuelwood	589 (98.2)	3 (0.5)	0
Twigs	84 (14.0)	7 (1.2)	0
Charcoal	20 (3.3)	0	0
Cowcake	29 (4.8)	1 (0.2)	2 (0.3)
Kerosene	17 (2.8)	2 (0.3)	549 (91.5)
Electricity	29 (4.8)	0	70 (11.7)
LPG	9 (1.5)	0	1 (0.2)

Figures in brackets are percentage of total sample size (N=600)

Table 4: Fuel use patterns for cooking purpose among sample households

User category (cooking only)	No. of hhs	% of total sample	Average annual income (in Rs)
Single fuel users	463	77.2	**16,755**
fuelwood only	*455*	*75.8*	
twigs only	*1*	*0.2*	
cowcake only	*1*	*0.2*	
kerosene only	*3*	*0.5*	
electricity only	*1*	*0.2*	
LPG only	*2*	*0.3*	
Multiple fuel users (two fuels)	101	16.8	**21,691**
fuelwood & twigs	*57*	*9.5*	
fuelwood & cowcake	*10*	*1.7*	
fuelwood & charcoal	*2*	*0.3*	
fuelwood & electricity	*18*	*3.0*	
fuelwood & kerosene	*11*	*1.8*	
fuelwood & LPG	*1*	*0.2*	
kerosene & LPG	*1*	*0.2*	
electricity & LPG	*1*	*0.2*	
Multiple fuel users (three fuels)	31	5.2	**37,542**
fuelwood, twigs & cowcake	*11*	*1.8*	
fuelwood, twigs & charcoal	*7*	*1.2*	
fuelwood, charcoal & cowcake	*2*	*0.3*	
fuelwood, twigs & kerosene	*1*	*0.2*	
fuelwood, twigs & electricity	*2*	*0.3*	
fuelwood, charcoal & electricity	*3*	*0.5*	
fuelwood, charcoal & LPG	*1*	*0.2*	
fuelwood, electricity & LPG	*3*	*0.5*	
LPG, electricity & kerosene	*1*	*0.2*	
Multiple fuel users (four fuels)	5	0.8	**25,941**
fuelwood, twigs, charcoal & cowcake	5	0.8	
All users	**600**	**100**	**25,482**

Table 5: Descriptive statistics different categories of fuelwood using households

Variable	Sellers (N=236)	Collection for own consumption (N=252)	Buyers (N=92)	Collection plus purchase (N=20)
caste_d (SC & ST =1, otherwise 0)	**0.7** *(0.5)*	**0.4** *(0.5)*	**0.1** *(0.2)*	**0.1** *(0.2)*
hhsadeq (no.)	**4** *(1.6)*	**4.3** *(1.7)*	**4.4** *(2.1)*	**5.3** *C*
yrsedn (years)	**5.5** (7.5)	10.5 (12.4)	26.5 (19.8)	16.2 (16.2)
tlndcult (acres)	**1.1** *(1.2)*	**1.3** *(1.5)*	**1.8** *(1.8)*	**2.6** *(3.9)*
annhhinc (rupees/year)	**14525** *(9727)*	***18294*** *(21765)*	***28606*** *(34603)*	**35016** *(40934)*
distf_vill (kms.)	**2.5** *(1.2)*	**3** *(1.4)*	**5** *(2.0)*	**4.3** *(1.6)*
lbtmcoll (hours/ref period)	**64.8** *(42.1)*	**46.1** *(34.2)*	- -	**29.8** *(30.0)*
fuelw_coll_yr (bharis/year)	**371.6** *(184.9)*	**178.4** *(95.9)*	- -	**100.5** *(72.6)*
fuelw_sale_yr (bharis/year)	**260.3** *(168.1)*	- -	- -	- -
fuelw_purch_yr (bharis/year)	- -	- -	**124.8** *(73.8)*	**108.6** *(103.0)*
fuelw_cons_yr (bharis/year)	**111.3** *(12.7)*	**178.4** *(95.9)*	**124.8** *(11.6)*	**209.1** *(136.8)*
Market value of fuelwood consumed per yeara (in Rs)	**1311**	**2213**	**1803**	**3168**

[a] *Upstream and downstream area fuelwood prices are, respectively, Rs10 and Rs15 per bhari*
Figures in brackets are standard deviations

Table 6: Quintile-wise (income based) mean estimates for different HH categories (fuelwood based)

Variables	Sellers (n=236)					Collection for own consumption (n=252)					Buyers (n=92)				
	q^1	q^2	q^3	q^4	q^5	q^1	q^2	q^3	q^4	q^5	q^1	q^2	q^3	q^4	q^5
SOURCE SISE ANNUAL INCOME (in Rupees)															
FARM	1568	3484	3175	4115	7676	2328	3550	5246	6088	21125	2694	5833	8544	6818	15003
%	**33.6**	**40.1**	**25.5**	**23.8**	**26.3**	**45.6**	**39.6**	**38.3**	**31.2**	**47.5**	**81.2**	**77.8**	**54.7**	**23.2**	**18.3**
WAGES	728	2073	5718	8307	13053	575	2744	5438	8236	10629	153	305	2645	2111	582
%	**15.6**	**23.9**	**45.9**	**48.1**	**44.7**	**11.3**	**30.6**	**39.7**	**42.3**	**23.9**	**4.6**	**4.1**	**16.9**	**7.2**	**0.7**
NON-FARM (EXCL WAGES)	31	140	328	570	2674	359	577	799	2780	9995	232	1358	4437	20089	66541
%	**0.7**	**1.6**	**2.6**	**3.3**	**9.1**	**7.0**	**6.4**	**5.8**	**14.3**	**22.5**	**7.0**	**18.1**	**28.4**	**68.8**	**81.0**
FOREST	2335	2992	3234	4292	5824	1838	2083	2231	2389	2739	240	0	0	188	28
%	**50.1**	**34.4**	**26.0**	**24.8**	**19.9**	**36.0**	**23.3**	**16.3**	**12.3**	**6.2**	**7.2**	**0.0**	**0.0**	**0.6**	**0.0**
TOTAL (annhhinc)	4662	8688	12455	17284	29226	5100	8955	13714	19493	44488	3320	7496	15630	29202	82157
%	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
ANNUAL FUELWOOD COLLECTION PURCHASE SALE & CONSUMPTION (bharis per year)															
COLLECTION (all sources)	361	347	341	386	454	157	178	169	192	212	0	0	0	0	0
PURCHASE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SALE	264	246	235	265	323	0	0	0	0	0	0	0	0	0	0
CONSUMPTION	97	101	106	121	131	157	178	169	192	212	55	97	111	148	220
OTHER VARIABLES															
HH SIZE (aded)	3.5	3.8	3.9	4.2	4.8	3.6	4.0	4.2	5.0	5.0	3.7	3.9	4.2	4.5	6.1
EDUCATION (yrsedn)	4.3	4.8	5.2	5.6	8.1	5.5	8.4	10.6	13.2	14.8	17.2	24.3	22.6	26.1	42.7
LANDHOLDING (tlndcult)	1.0	1.1	0.8	1.0	1.5	1.0	1.4	1.4	1.1	1.6	1.5	1.4	2.1	1.8	2.4
LIVESTOCK (lvstksiz)	3.3	5.1	3.6	3.3	4.1	2.3	2.6	2.1	2.7	3.2	1.4	2.1	2.6	2.5	2.6

Note: Farm income consists of income from agriculture fishing and livestock

Table 7: Variables of the 2SLS probit model

Variable	*Definition*	*Expected sign of probit estimates*
*region_d	dummy for region (downstream irrigated area=1, 0 otherwise)	+
*distf_vill	distance to forest from village in kms.	+
*source_d	dummy for non-forest sources of fuelwood, such as roadside trees, trees in private landholdings, social forestry projects, etc (other than forest=1, 0 otherwise)	-
*caste_d	dummy for caste (SC&ST households=1, 0 otherwise)	-
*yrsedn	total years of education for the household as a whole (no. of years)	+
*hhsadeq	household size in adult equivalent terms (number)	+/-
*hhsadeq2	square of 'hhsadeq'	+/-
*tlndcult	total land cultivated by household (in acres)	+
*tlndcult2	square of 'tlndcult'	+/-
*lvstksiz	size of livestock holding, measured as the present stock of cows, buffaloes, oxen & bullocks (number)	+
electy_hh	dummy for household access to electricity (electricity user household=1, 0 otherwise)	+
lpg_vill	dummy for village access to LPG (access, as indicated from the presence of LPG user households in the village =1, 0 otherwise)	+
nonwage_inc	annual non-wage earnings of household from non-farm sector (rupees)	+
nonwage_inc2	square of 'nonwage_inc'	+/-
@wage_inc	annual wage earnings of household (rupees)	+
wage_inc2	square of 'wage_inc'	+/-
buyer_d	dummy for fuelwood purchasing household (buyer=1, 0 otherwise)	
#lbtmcoll	total labour time spent by household members for collection of fuelwood in reference period (hours)	
*sxratio	household sex ratio (adult females as % of adult total)	

@ values predicted from IV (2SLS) regression
# instrumented variable
* instruments

Table 8: IV (2SLS) estimation of the 'wage_inc' equation

Variable	*First-stage regression*	*IV (2 SLS) regression*
	Instrumented variable: *lbtmcoll*	Dependent variable: *wage_inc*
lbtmcoll	-	-0.009 (-3.71)*
region_d	0.758 (0.15)	-0.146 (-2.45)*
hhsadeq	13.819 (4.48)*	0.243 (3.94)*
hhsadeq2	-0.737 (-2.71)*	-0.011 (-2.25)*
yrsedn	-0.782 (-5.66)*	-0.021 (-6.75)*
sxratio	-0.073 (-0.83)	-0.0002 (-0.12)
tlndcult	-4.244 (-2.26)*	-0.134 (-4.51)*
tlndcult2	0.221 (1.08)	0.010 (3.03)*
lvstksiz	0.913 (2.33)*	-0.012 (-1.78)*
source_d	19.640 (4.69)*	-
distf_vill	-2.373 (-1.80)*	-
caste_d	14.257 (3.41)*	-
constant	14.419 (1.40)	0.632 (4.05)*
Number of obs.	600	600
F	15.36*	11.88*
Adj R-squared	0.21	-

* significant at the 1% level

Table 9: Probit estimation of the marginal effects of fuelwood purchase determinants

Dependent variable: *buyer_d*	-
Variable	Marginal effect: dF/dx
region_d	0.00027 (0.02)
distf_vill	0.00931 (3.12)*
electy_hh	0.01954 (2.01)*
lpg_vill	0.02065 (1.77)*
source_d	-0.00342 (-0.42)
caste_d	-0.05328 (-4.51)*
hhsadeq	-0.04173 (-5.90)*
hhsadeq2	0.00272 (4.37)*
yrsedn	0.00230 (7.01)*
tlndcult	0.01750 (4.83)*
tlndcult2	-0.00124 (-3.49)*
lvstksiz	0.00047 (0.45)
wage_inc (predicted)	0.10726 (4.01)*
wage_inc2	-0.00362 (-0.20)
nonwage_inc	4.86e-07 (1.61)
nonwage_inc2	-1.93e-12 (-0.78)
Number of obs.	600
LR chi2 (16)	390.83*
Pseudo R-squared	0.68

* significant at the 1% level

Table 10: WTP estimates

Study area	Variable	Income quintiles				
		q1	q2	q3	q4	q5
Upstream	mean annual household income per capita (rupees)	**1113** *(278)*	**1971** *(276)*	**3144** *(339)*	**4526** *(643)*	**8872** *(4499)*
	mean WTP per household member (rupees)	**9.2** *(32)*	**4.7** *(12)*	**8.6** *(25)*	**7.6** *(30)*	**44.5** *(131)*
	mean WTP as % of mean annual household income per capita (%)	**0.8**	**0.2**	**0.3**	**0.2**	**0.5**
Downstream	mean annual household income per capita (rupees)	**1478** *(491)*	**2635** *(289)*	**3606** *(305)*	**5365** *(613)*	**13012** *(8722)*
	mean WTP per household member (rupees)	**122.7** *(133)*	**126.5** *(175)*	**120.1** *(161)*	**158.8** *(219)*	**337.7** *(317)*
	mean WTP as % of mean annual household income per capita (%)	**8.3**	**4.8**	**3.3**	**3.0**	**2.6**

FIGURES

Figure 1: Conceptual framework

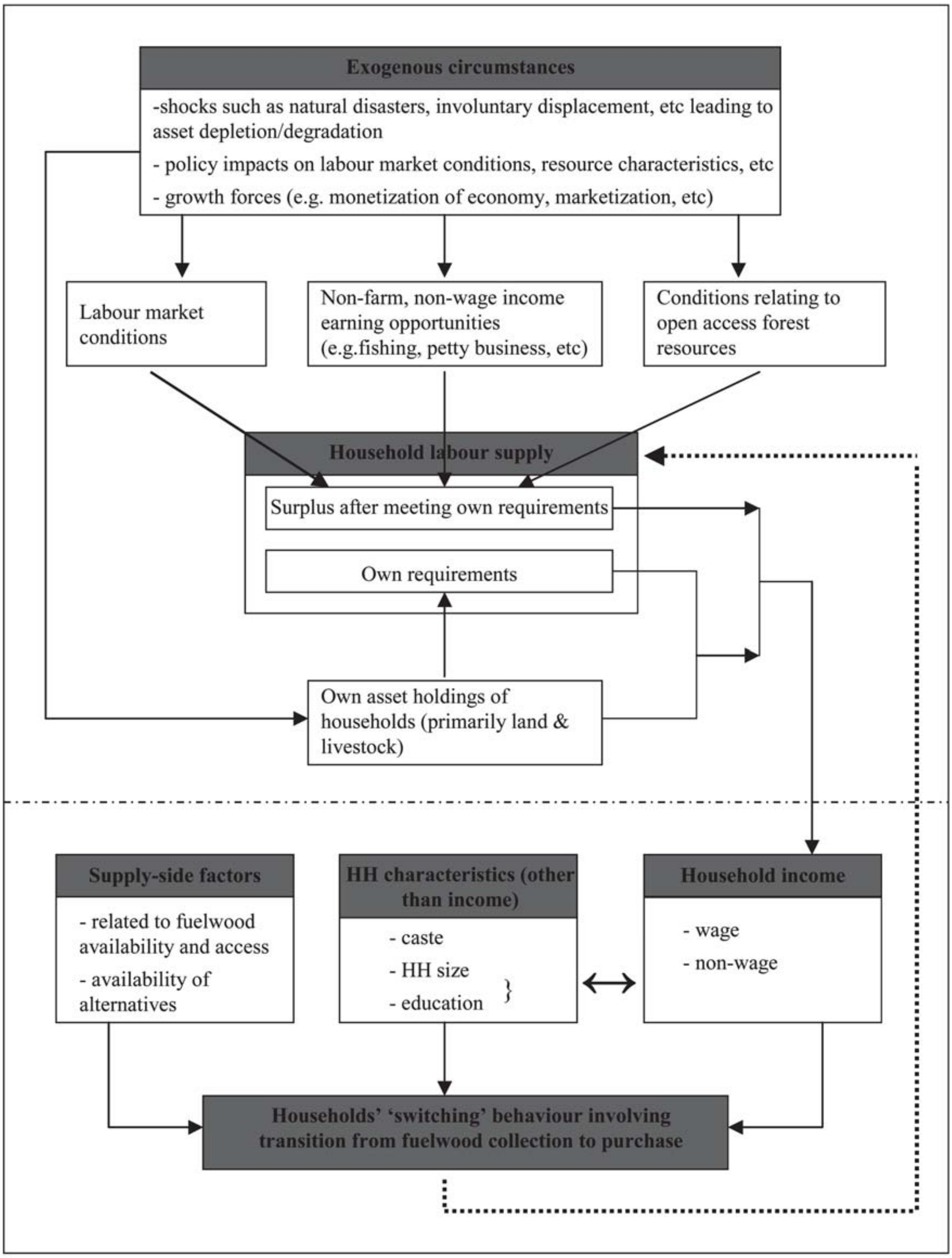
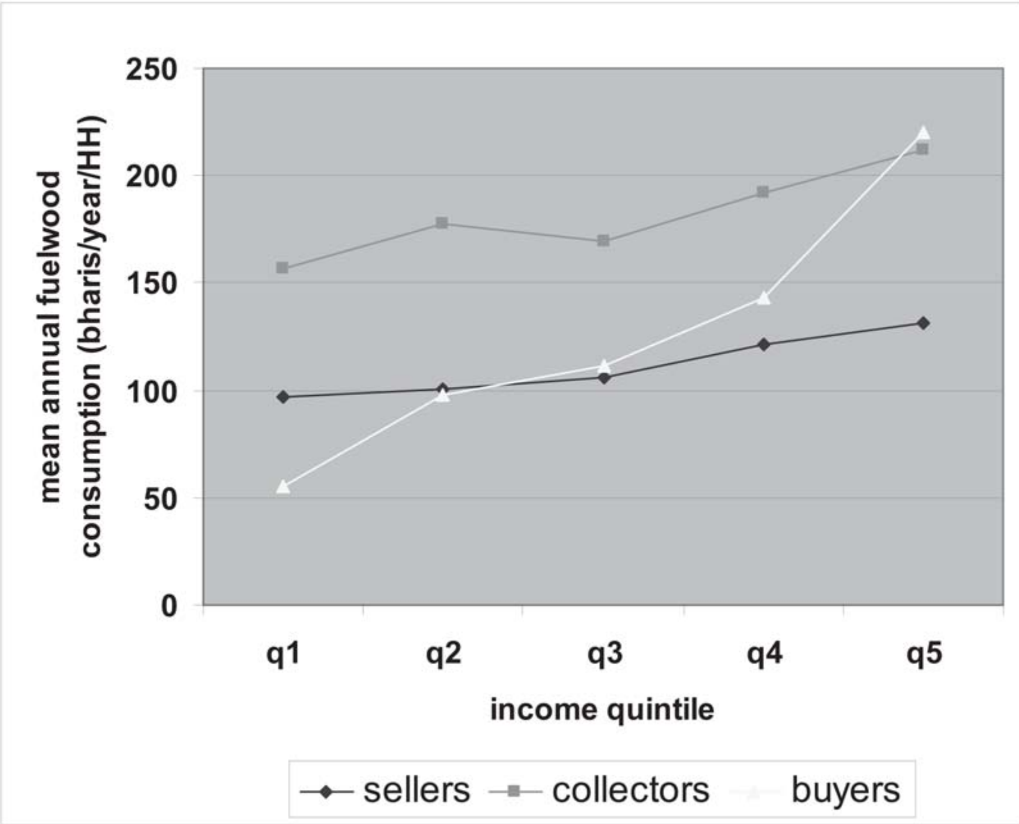


Figure 2: Income quintile-wise mean annual fuelwood consumption for different HH categories



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