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RESEARCH ARTICLE

ENERGY CONSUMPTION AND LABOUR ALLOCATION IN RURAL PURULIA: A MODEL FOR HOUSEHOLD RESPONSES TO FUELWOOD SCARCITY

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ABSTRACT

Subsistence households residing in the remote areas are principally dependent upon the forest for meeting their daily needs. They have very limited access to commercial fuels and therefore tend to rely on forest fuelwood to serve as a source of energy. However, in the face of forest scarcity they substitute other bio-fuels like agricultural crop residue, dung and fuelwood from trees on private land for forest fuelwoood. Although some studies have tried to analyse these issues, not much research have been made till date on this area. This paper addresses the problems associated with fuelwood production and consumption in the rural areas of Purulia district of West Bengal. Household responses to forest scarcity are analysed by a non-separable household model focusing on the prospects of fuel substitution. Based on primary data from six villages located on the Ajodhya Hills of Purulia OLS technique and probit model are fitted for estimation. It is observed that instead of reducing fuelwood collection from the forest, households respond to the scarcity by increasing its consumption. Substitution of forest fuelwood is noted only when number of trees on private land increases although the result turns out to be insignificant. This indicates that there are hardly any alternatives to forest fuelwood in the rural areas especially when the forest resources are available for free to the inhabitants residing in the vicinity of the forests.

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INTRODUCTION

Energy is the fundamental and most vital input for maintaining the minimum quality of life. It is essential for the welfare of the households in the developing countries. Majority of the population are denied access to modern fuels and therefore, have to depend on biomass fuels such as fuelwood, crop residues and animal dung for energy (Barnes and Sen, 2000; Parikh *et al.*, 1999; Saxena, 1999; Singh *et al.*, 1994; Laxmi *et al.*, 2003). Most of the fuelwood is gathered from the forest in the rural areas (Cecelski, Dunkerley, and Ramsey, 1979). Biomass fuels supply 35% of the energy in developing countries (World Bank, 1992). According to International Energy Agency (IEA), about 2.7 billion people in the developing countries, 82% of which reside in rural areas, rely on wood, tree leaves, etc., for cooking using inefficient devices like 3-stone fire stove, mud stoves and brick stoves without any chimneys or hoods (Waris and Antahal, 2014). During the past few decades the Indian economy has been experiencing many quantitative as well as qualitative changes in its energy consumption patterns (CMIE 2001). This is mainly the result of growing population and increased need for economic development. The household sector alone accounts for 30% of the final energy consumption (excluding energy used for transport) – a finding that underlines the importance of that sector in the total national energy scenario (Reddy, 2003). The rural population of the country is primarily reliant upon traditional biomass fuels including fuelwood, animal dung and crop residues. The household consumer expenditure survey conducted by NSSO during 2007-2008 revealed that about 77% of the rural households continued to use firewood and chips to meet their energy needs for cooking, over 7% used dung cake while only 9% relied on LPG. Forest fuelwood constitutes the principal component of domestic energy for rural India. With increasing population pressure, firewood demand far outstrips the supply thereby resulting in deforestation and forest degradation (Status Report on use of Fuelwood in India). Analyses have been made on the determinants of fuelwood demand and the linkage between fuelwood collection and forest degradation in the context of developing countries. Heltberg *et al.* (2000) studied the

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response of fuelwood collecting households to forest scarcity and the substitution possibilities of fuelwood by other private energy sources, viz., dung, crop residue and trees on private farm in rural India. In a study on Nepal, Amacher *et al*. (1996) found that rural households respond to deforestation by using their own land for fuelwood production and that, factors such as market prices, labour opportunities, availability of substitutes and access to the forest are the major determinants of fuelwood production and consumption. Chen *et al*. (2006) analysed the factors determining choice of energy source and labour input to fuelwood collection in the poor forest-rich regions of China. They noted that greater distance to the forest instigates substitution away from fuelwood collection and promotes the use of coal as an alternative source of energy. A study made by Palmer and MacGregor (2009) on Namibia however concluded that substitution from fuelwood to other fuels is limited by the declining availability of forest stock – an observation that conforms to the case of South Asia.

The purpose of this paper is to address the issues related to energy consumption and fuel substitution in the context of the rural economy of Purulia. In particular, the prime objectives of the study are:

- To analyse the factors determining fuelwood collection from the forest
- To analyse the determinants of labour allocation to fuelwood production
- To examine the prospects of fuel substitution in the event of forest scarcity

MATERIALS AND METHODS

The data used for this study were collected from villages within the ambit of the Ajodhya Hills of Purulia during the period from June 2013 to December 2013. The sample frame was defined for all villages that depended partly or fully on the forest for fuelwood, food and fodder. A well structured questionnaire was administered to 197 randomly selected households residing in six villages in the study area. The selection of villages was made on the basis of forest access and forest use. Since forest access within a village depends on the location of the homestead and the terrain, such a selection process captures the heterogeneities inherent in the characteristics of the households across the villages. Information was gathered on the socio-economic conditions, demographics, type of products procured by the households from the forest and quantity of sales (if any) and level of consumption. The household was considered as the unit of analysis. The study investigates the issues related to fuelwood collection and labour allocation by an analytical model for domestic fuel supply and demand with focus on substitution between forest fuelwood and fuelwood collected from private land as an alternative source of domestic energy. Since many of the households in the study area were found not to participate in fuelwood sales but to be self sufficient in fuelwood production, the market for fuelwood to such households is considered to be missing. Hence the model is formulated in the tradition of a non-separable (or non-recursive) household model which yields a set of reduced form equations. Three equations relating to forest fuelwood collection, labour allocation for the activity and private energy collection were estimated – the first two by the OLS technique and the last one by a probit regression.

Energy Characteristics of the Study Area

Purulia is a backward district lying in the western-most part of West Bengal. The district is characterized by undulating topography with arid hilly terrains in the western and southern parts. Ajodhya Hills, to which the study is related, are located in the southwest of Purulia. Owing to abject poverty, most of the peasant households on the hills have no fuel-driven vehicles of their own (only 3.5% of the households reported having motorbikes). However, the villagers of the study area mostly travel to the forest on foot and rarely by bicycles. Instead of tractor they use animal power for farming purposes. Hence, they hardly require any fuel for agriculture. Table 1 reports the use of different energy sources for cooking, space heating and lighting by the surveyed households. As evident from the table, all the peasant households residing on the Ajodhya Hills depend on fuelwood for cooking as well as space heating during the winter. Forests are the main source of fuelwood for all the households considered in the survey, resorting to their own private lands only occasionally during the times of difficulty to supplement the forest fuelwood supply. Moreover, no fuel other than fuelwood is used to light their fires. Electricity is available to more than half of the households of Bhuighara and Barelahar (about 52.5% and 52% respectively), 19.61% of the households of Saharjuri and a few households of Tarpania (3.57%) and Bagandi (3.03%), who resort to kerosene lamps (called *dibi*) to light their houses only when the electricity supply is interrupted. However, the households that are devoid of electricity have to depend solely on kerosene lamps for

Table 1. Energy Consumption by Type of End Use and Energy Source by the Surveyed Households

Village	Percentage of Households Using Energy Source					
	For Lighting		For Cooking		For Heating	
	Electricity	Kerosene	Fuelwood from Forest	Fuelwood from Private Land	Fuelwood from Forest	Fuelwood from Private Land
Bagandi	3.03	100	100	33.33	100	33.33
Bhuighara	52.50	100	100	97.50	100	97.50
Saharjuri	19.61	100	100	88.23	100	88.23
Tarpania	3.57	100	100	78.57	100	78.57
Barelahar	52.00	100	100	84.00	100	84.00
Kamlabahal	0	100	100	100	100	100
Total	23.35	100	100	80.20	100	80.20

Source: Field Survey (2013)

lighting purposes. Fuelwood sellers constitute 53.30% of the sample (i.e., 105 households) of the hills. Marketed fuelwood constitute 64.37% of the total fuelwood collection for the sellers and 50.86% of the fuelwood collection of the entire sample of 197 households. Fuelwood from private land is used mostly by the households as a substitute for forest fuelwood. The villages show considerable variation in forest access. Of all the villages considered in the survey, Bagandi enjoys the best access, being the most proximate village to the forest (at a distance of about 1.06 Km) while Kamlabahal is farthest from the forest stock (being nearly 3.70 Km away) and therefore has the poorest access.

The Household Model for Rural Energy Supply

In India commercial fuels are used in urban areas. However, in the rural belts of India and particularly of the Purulia district there is predominance of non-commercial fuels like fuelwood collected from the forests, village commons, roadsides and private lands. Other traditional cooking fuels include crop residues from the farm and dung obtained from domesticated animals. The joint production and consumption of such traditional solid fuels calls for the use of a household model as against a pure demand model (Singh, Squire and Strauss, 1986; Heltberg *et al*., 2000). Moreover, the fact remains that markets for domestic fuels are either rare or even if present, are ill-functioning. This suggests the use of a non-separable household model for energy demand and supply. In addition to this, a situation of non-separability between household labour demand and supply is also indicated by the prevalence of labour market imperfections in the rural areas. Such an assumption therefore entails the joint determination of household resource allocation, farm and off-farm labour supply rather than being determined recursively.

The model presented below captures the situation of a peasant household engaged in crop production, farm and off-farm wage work and wood collection. We consider a simple agricultural household model representing firewood consumption. The household derives utility from the consumption of home cooked food, C_N, which requires energy; market purchased goods, C_M, which do not require energy; and leisure time C_L of all the working family members which includes cooking time and other household activities. Utility is conditioned on a vector of household characteristics which are supposed to influence the household preferences, Z_c, such as household size, average years of schooling of the household and type of the house:

$$U = U(C_N, C_M, C_L; Z_c) \tag{1}$$

The agricultural production function of the farm household can be written as:

$$q_{AG} = g_{AG}(L_{AG}, inp, A_o; Z_h) \tag{2}$$

where L_{AG} denotes labour units employed in performing agricultural activities which is a function of household labour (L_H) and hired labour (L_D) that may be imperfect substitutes. Accordingly,

$$L_{AG} = h(L_D) + L_H; \tag{3}$$

$$h(L_D) \in (0, L_D)$$

The function $h(L_D)$ is a hired labour efficiency index used to convert hired labour units into household labour units. It takes the value zero if hired labour is absolutely inefficient and L_D if hired labour is as efficient as household labour (Barrett, 1999). The variable 'inp' in expression (2) denotes the use of agricultural crop residues and dung as farm inputs. The total amount of agricultural residue and dung available is modeled as a fixed proportion of agricultural output (βq_{AG}) used entirely as a manure (i.e., inp = βq_{AG}); A_o denotes endowment of land which is assumed to be historically given. Z_h is a vector of other household endowments pertaining to farming (e.g, big livestock including cattle and buffaloes). Big livestock contribute to agricultural production primarily through the generation of manure and are also used as draft power. For meeting its nutritional needs, the household faces the choice of either consuming the products of own farm labour or purchasing the staple food crops from the market. Further, it may be possible that the household sells a part of its own farm produce for cash earnings. Taking all the possibilities into account the household's consumption of agricultural good could be represented by the sum total of its own farm produce that is retained within the household (αq_{AG}; $0 \leq \alpha \leq 1$) for self consumption and the amount purchased from the market (C_X).

Composite household food requiring energy (C_N) is therefore produced by applying fuel inputs obtained from forest and non-forest sources to agricultural food crops and is denoted by the production function:

$$C_N = r(C_{FW}, C_{PE}, C_{AG}) \tag{4}$$

where, consumption of fuelwood from the forest and village commons is labeled C_{FW}, non-forest energy fuel is denoted by C_{PE} (constituting fuelwood from trees on own farm) and consumption of agricultural goods (obtained from own farm produce as well as market purchase) is labeled C_{AG}, defined as:

$$C_{AG} = \alpha q_{AG} + C_X \tag{5}$$

Extraction of fuelwood from trees on private land is described by the concave production function:

$$q_{PE} = g_{PE}(L_{PE}, T_R) \tag{6}$$

where L_{PE} represents labour allocated for private energy collection and T_R denotes number of trees on private land. A production function describing collection of fuelwood from forests is represented as:

$$q_{FW} = g_{FW}(L_{FW};\ Z_v) \tag{7}$$

where, L_{FW} denotes labour units that the household supplies for collecting fuelwood from the forest; Z_v is a vector of characteristics describing forest stock and access conditions including population relative to forest area and state of the forest, measured by the time price of collecting fuelwood. State of the forest is supposed to capture the degree of deforestation the households face and is defined as the time taken to collect a bundle of firewood from the forest (Bluffstone, 1995). Technology $g_{FW}(\bullet)$ describes forest "thinning" activities in which household labour is employed to collect fuelwood from the forest (Fisher, Shively and Buccola, 2005). Just as the household can hire in agricultural labour, so can it hire out its own labour for farm wage work (L_S) and off-farm wage work (L_{OUT}) at parametric wage rates, w_F and w_{OF} respectively. The budget constraint thus facing the household is:

$$P_{FW}(q_{FW} - C_{FW}) + P_{AG}(1-\alpha)q_{AG} + w_F(L_S - L_D) + w_{OF}L_{OUT} + E_x = P_M C_M + P_{AG}C_X \quad (8)$$

The left hand side of expression (8) gives the income from various sources – $w_{OF}\, L_{OUT}$ is the earnings from off-farm wage work; $w_F\,(L_S - L_D)$ is net wage earnings from working as farm labour; $P_{FW}\,(q_{FW} - C_{FW})$ is net income from fuelwood sales; $P_{AG}(1 - \alpha)q_{AG}$ denotes income from sales of the remaining portion of the agricultural produce that are not consumed within the household and E_x denotes other incomes. The right hand side gives expenditure on agricultural products ($P_{AG}C_X$) and on other consumption goods ($P_M C_M$) purchased from the market. The variables P_{FW}, P_{AG}, P_M denote price of fuelwood, agricultural goods and other consumption goods respectively, other consumption goods respectively. Leisure is given as $C_L = T - L_H - L_S - L_{OUT} - L_{PE} - L_{FW}$, where T is time endowment of the working members of the household. Motivated by field observations it is assumed that the households procure all fuelwood from the forest with their own labour without making any purchases. However, some of the households may indulge in fuelwood sales. The net marketed amount of fuelwood is therefore non-negative:

$$q_{FW} - C_{FW} \geq 0 \quad (9)$$

Private energy, in contrast, is assumed to be collected only for self consumption which implies $q_{PE} = C_{PE}$. In addition, the following non-negativity constraints apply:

$q_i \geq 0$; $C_j \geq 0$; $L_k \geq 0$;
i = FW, AG, PE;
j = N, M, AG, FW, PE, L, X;
k = FW, AG, OUT, PE, D, S, H (10)

The Lagrangian for an internal solution to the problem consisting of (1) – (10) can be written as:

$$\ell = U[C_M, r(C_{FW}, q_{PE}, \alpha q_{AG} + C_X), T - L_H - L_S - L_{OUT} - L_{PE} - L_{FW}; Z_c] - \lambda[P_M C_M + P_{AG} C_X - P_{FW}(q_{FW} - C_{FW}) - P_{AG}(1 - \alpha)$$

$$q_{AG} - w_F(L_S - L_D) - w_{OF} L_{OUT} - E_x] - \eta_{AG}[q_{AG} - g_{AG}(h(L_D) + L_H, \beta q_{AG}, A_o; Z_h)] - \eta_{FW}[q_{FW} - g_{FW}(L_{FW}; Z_v)] - \eta_{PE}[q_{PE} - g_{PE}(L_{PE}, T_R)] - \mu[C_{FW} - q_{FW}] \quad (11)$$

The Kuhn-Tucker conditions for this problem are

$$\frac{\partial \ell}{\partial C_{FW}} = \frac{\partial U}{\partial \Gamma}\frac{\partial \Gamma}{\partial C_{FW}} - \lambda P_{FW} - \mu = 0$$
$$\frac{\partial \ell}{\partial q_{FW}} = \lambda P_{FW} - \eta_{FW} + \mu = 0$$
$$\frac{\partial \ell}{\partial L_{FW}} = \eta_{FW}\frac{\partial g_{FW}}{\partial L_{FW}} - \frac{\partial U}{\partial C_L} = 0$$
$$\frac{\partial \ell}{\partial q_{PE}} = \frac{\partial U}{\partial \Gamma}\frac{\partial \Gamma}{\partial q_{PE}} - \eta_{PE} = 0$$
$$\frac{\partial \ell}{\partial L_{PE}} = \eta_{PE}\frac{\partial g_{PE}}{\partial L_{PE}} - \frac{\partial U}{\partial C_L} = 0$$
$$\frac{\partial \ell}{\partial C_M} = \frac{\partial U}{\partial C_M} - \lambda P_M = 0$$
$$\frac{\partial \ell}{\partial C_X} = \frac{\partial U}{\partial \Gamma}\frac{\partial \Gamma}{\partial C_{AG}} - \lambda P_{AG} = 0$$
$$\frac{\partial \ell}{\partial q_{AG}} = \frac{\partial U}{\partial \Gamma}\frac{\partial \Gamma}{\partial C_{AG}}\alpha + \lambda(1-\alpha)P_{AG} - \eta_{AG}\left(1 - \beta\frac{\partial g_{AG}}{\partial inp}\right) = 0$$
$$\frac{\partial \ell}{\partial L_H} = \eta_{AG}\frac{\partial g_{AG}}{\partial L_H} - \frac{\partial U}{\partial C_L} = 0$$
$$\frac{\partial \ell}{\partial L_S} = \lambda w_F - \frac{\partial U}{\partial C_L} = 0$$
$$\frac{\partial \ell}{\partial L_D} = \eta_{AG}\frac{\partial g_{AG}}{\partial h}\frac{\partial h}{\partial L_D} - \lambda w_F = 0$$
$$\frac{\partial \ell}{\partial L_{OUT}} = \lambda w_{OF} - \frac{\partial U}{\partial C_L} = 0$$

$$q_{FW} - C_{FW} \geq 0;\ \mu \geq 0;\ \mu(q_{FW} - C_{FW}) = 0 \quad (12)$$

Rearranging the first order conditions it is found that

$$\frac{\partial U}{\partial C_L} = \eta_{AG}\frac{\partial g_{AG}}{\partial L_H} = \frac{\partial U}{\partial \Gamma}\frac{\partial \Gamma}{\partial C_{FW}}\frac{\partial g_{FW}}{\partial L_{FW}} = \frac{\partial U}{\partial \Gamma}\frac{\partial \Gamma}{\partial q_{PE}}\frac{\partial g_{PE}}{\partial L_{PE}} = \lambda w_F = \lambda w_{OF} \quad (13)$$

Expression (13) states that households allocate their labour to own-farm cultivation, fuelwood collection and other private energy collection in such a way that the value of marginal product of labour across all these activities is equal to marginal utility of leisure. If no time allocation exists at which this equality holds, i.e., if the marginal product of labour allocated to these activities is lower than the marginal utility of leisure at any hour of work, the household would not perform any of these activities. Instead, it should take up other remunerative jobs that are available (like working on others' farms as agricultural labourers), should that yield higher returns than the previously mentioned activities (Galasi, 1994). The hours to be devoted for working on others' farms would be determined at the point where the wage offered equals the marginal utility of leisure. The same argument holds with respect to off-farm wage work.

Empirical Specification

The first order conditions yield a set of reduced form equations for fuelwood collection, amount of time allocated for its collection and private energy production as functions of exogenous variables:

$$\left.\begin{matrix} q_{FW} \\ L_{FW} \\ q_{PE} \end{matrix}\right\} = f(Z_c, Z_h, Z_v, T_R, P_{AG}, P_M, P_{FW}, w_F, w_{OF}, T, E_x) \quad (14)$$

The above set of equations form the basis of our empirical work that are used to investigate the influence of the exogenous variables on fuelwood collection, labour inputs to fuelwood collection and private energy collection for the rural households of the study area. The household characteristics pertaining to consumption (Z_c) are represented by household size and years of education of the household head. Four variables are used to represent the forest stock and access conditions (Z_v). The stock of forest resources is measured by the ratio of population to forest area, such that, the higher the population relative to the forest area the lower is the forest stock and hence higher is the scarcity. Another measure of forest resource scarcity is time taken to collect a bundle of fuelwood from the forest. It is conjectured that the higher the time required for collection the higher is the level of scarcity. Forest access is measured by the distance of the forestland from the house and membership status in forest protection committees.

The household endowments pertaining to farming (Z_h) are represented by size of cultivable land and cattle holdings. The number of trees on private land (T_R) and size of landholding are deemed to indicate the relative scarcity of private energy (which in our study pertains to fuelwood collected from private land). Time endowment of the household (T) is represented by the number of working members. Prices of agricultural goods (P_{AG}), other purchased goods (P_M) and fuelwood (P_{FW}) are assumed not to vary across the households and villages. Hence they were not included among the regressors. Also, farm and off-farm wage data (w_F and w_{OF}) are missing for a number of households. Instead, a discrete variable, viz., years of education of the household head is included to address the labour market opportunities available to the household. Income from other sources (E_X) consists of other non-wage-non-agricultural earnings, which also includes remittances received from migrants and social pensions from the government. The first two equations relating to forest fuelwood collection and labour allocation are estimated by the OLS technique. The model is represented as:

$$Y_i = X_i\beta + u_i \tag{15}$$

where Y_i is the dependent variable under study and X_i represents the set of explanatory variables supposed to influence Y_i. u_i is the random disturbance term, such that $u \sim N(0, \sigma^2)$.

The unavailability of any quantitative data relating to private energy collection, however, hinders our analysis on the possibility of fuel substitution. Instead, we use qualitative data to denote as to whether the household had collected wood from private land to supplement forest fuelwood supply during the 12 months prior to the survey or not. Accordingly, we fit a probit model to estimate the third equation relating to private energy consumption. The model takes the form:

$$W_i^* = Z_i\gamma + \varepsilon_i \tag{16a}$$

where, W_i^* is the latent variable that indexes the benefit derived from private energy consumption. W_i is the dichotomous variable following the rule:

$$\begin{aligned} W_i &= 1 \quad \text{if} \quad W_i^* > 0 \\ &= 0 \quad \text{otherwise} \end{aligned} \tag{16b}$$

i.e., W_i assumes the value one when the household consumes private energy and zero otherwise. ε_i is the error term, such that $\varepsilon_i \sim N(0,1)$. Table 2 presents the definition of variables and the expected sign they are to hold with the dependent variables under study.

RESULTS AND DISCUSSION

Table 3 reports the results of OLS regression of the first two equations relating fuelwood collection from forest and labour allocation for the said purpose as well as elasticities evaluated at the mean of the data. In addition, it shows the probit regression results for private energy consumption and the corresponding marginal effects. An increase in the time taken to collect a *bojha* of fuelwood increases fuelwood collection from the forest which is opposite to what was expected. Its influence on labour allocation and likelihood of private energy consumption is also positive although the effect on the latter is negligible. A 10% rise in per unit collection time raises forest fuelwood collection by 3.6% and labour allocation by 9.3%. This is perhaps because the households want to stack fuelwood at home as reserves in anticipation of even harder times in the near future and therefore allocate more labour for its collection.

Table 2. Definition of Variables

Explanatory Variables	Definition	Expected Signs		
		Forest Fuelwood Collected (FFWC)	Labour Allocation to Forest Fuelwood Collection (LFWC)	Fuelwood Collection from Private Land (FWPL)
Timefwc	Time taken to collect 1 *bojha* of forest fuelwood	-	+/-	+
Working	Number of working members in the household	+	+	+/-
HHSize	Size of the household	+	+	+/-
Land	Size of land holdings of the household, in *Bigha*	-	+/-	+/-
Big Livestock	Cattle and buffalloes owned by the household, in Tropical Livestock Units (TLU)	-	+/-	+/-
Trees	Number of trees on private land	-	-	+
Yrsed	Education of the household head, in Years	-	-	+/-
Inc	Income from other sources, in Rs.	+/-	+/-	+/-
Forstock	Population per unit area of forest, in Ha^{-1}	-	+/-	+
Disthf	Distance of house from forest, in min.	-	+/-	+
Memfpc	Dummy =1 if the household is a member of forest protection committee	+	+	+/-

Note: 1 *Bojha* of fuelwood = 45kg – 50 kg; 1 *Bigha* of land = 0.13 hectare.

Increase in the working members lead to an increase in fuelwood collection from the forest and labour allocation as expected. More working members imply more labour available for all activities including fuelwood collection and hence higher amount of fuelwood collected to meet additional cooking requirements for larger army of workers performing strenuous work. A similar effect is observed in case of an increase in size of the household on forest fuelwood collection and labour allocation as it increases the demand for food requiring energy and hence asks for more labour to be spent on fuel collection. The impact of these two factors on private energy consumption is however insignificant and negative. Increase in trees on private land leads to a reduction in forest fuelwood collection and labour allocation although the effect is insignificant. It also leads to a significant increase in the likelihood of private energy consumption. Other two measures of scarcity, namely forest stock and distance of the house from forest, have positive impacts on forest fuelwood collection, labour allocation and private energy consumption for reasons very similar to the ones cited in favour of the previous measure of scarcity, viz., collection time per unit of fuelwood from the forest. A 10% rise in population per hectare of forest area is likely to bring about almost 3.7% increase in forest fuelwood collection and 1.7% rise in labour allocation, although the influence on the latter is insignificant. Moreover, a 10% increase in the distance from house to the forestland is associated with 1.2% rise in forest fuelwood collection and 4.4% rise in labour allocation for the activity. Its effects on forest fuelwood collection and the likelihood of private energy consumption are however, insignificant. Membership in forest protection committee casts a significantly negative influence on forest fuelwood collection

Table 3. Regression Results for Fuelwood Collection and Private Energy Consumption

Variable	OLS		OLS		Probit		Variable Mean
	Amount of Forest Fuelwood Collection		Labour Input to Forest Fuelwood Collection		Private Energy Consumption		
	Parameter[a]	Elasticity[b]	Parameter[a]	Elasticity[b]	Parameter[a]	Marginal Effect[c]	
Timefwc	.0034874	.3610453***	.00902	.9338262***	.0137785	.0005351	103.528
	(2.65)***		(5.97)***		(1.91)*		
Working	.1190783	.3330565***	.1321485	.3696132***	-.0564675	-.0021929	2.79695
	(3.18)***		(3.08)***		(-0.29)		
HHSize	.0657078	.3141968***	.07955	.3803863***	-.0877159	-.0034064	4.78173
	(2.82)***		(2.97)***		(-0.77)		
Land	.0108095	.0362771	.0141307	.0474234	.1055619	.0040995	3.35605
	(0.88)		(1.00)		(1.07)		
Big Livestock	-.033425	-.0699294	-.0322428	-.0674562	.097573	.0037892	2.09213
	(-1.60)		(-1.35)		(0.82)		
Trees	-.0000983	-.0145208	-.0001177	-.0173945	.0106624	.0004141	147.746
	(-0.43)		(-0.45)		(3.28)***		
Yrsed	-.0049644	-.0102312	-.00091	-.0018754	.1271625	.0049383	2.06091
	(-0.43)		(-0.07)		(2.06)**		
Inc	-2.53e-06	-.0312513	-2.30e-06	-.0283836	-4.34e-06	-1.69e-07	12352.9
	(-1.41)		(-1.12)		(-0.44)		
Forstock	.1527971	.3663719***	.0728278	.1746241	.4492022	.0174446	2.39777
	(3.65)***		(1.51)		(2.84)***		
Disthf	.0028152	.1204667	.0101815	.4356859***	.0038965	.0001513	42.7919
	(1.15)		(3.63)***		(0.30)		
Memfpc	-.5306162		-.5361688		-.5244298		.3553299
	(-3.37)***		(-2.96)***		(-0.60)		
Constant	4.093188		4.360982		-2.090293		
	(27.88)***		(25.86)***		(-2.76)***		
R^2	0.3368		0.6296				
Pseudo R^2					0.5127		
Prob > chi square					0.0000		
Log Likelihood					-49.098445		

[a] *t*-values in parentheses; [b] Elasticities evaluated at the mean; [c] Marginal Effects evaluated at the mean.* Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level.

This indicates that fuelwood obtained from trees on private land act as a substitute for forest fuelwood. Years of education of the household head also casts a negative but insignificant influence on forest fuelwood collection and labour allocation and a positive significant effect on the likelihood of private energy consumption. This may imply that households with more educated heads have greater employment opportunities in more remunerative jobs and hence spend lesser time in inferior activities such as forest fuelwood collection. Moreover, an increase in the level of education enhances the awareness of the household regarding the detrimental consequences of forest overuse and thereby, motivates them to conserve the forest resources by controlling fuelwood extraction. Rather, it increases their propensity to collect fuelwood from trees grown on own private lands to meet their energy needs.

and labour allocation, contrary to what was expected. This is perhaps because the members are aware of the forest rules and hence develop an interest in conserving the forest resources for the future generations. Its influence on private energy consumption is insignificant and negative. The factors such as size of landholdings, cattle holdings and income from other sources do not have any significant influence upon any of the dependent variables under study.

Conclusion

This paper examines the factors determining choice of energy source and labour allocation to fuelwood collection from the forest on the basis of primary data from the Purulia district of West Bengal. The study presents a household model for domestic energy demand and supply from which three equations relating to fuelwood collection from forest and labour allocation were derived and estimated using OLS technique and probit regression to analyse the likelihood of fuel substitution. The results obtained contradict our expectations regarding the influence of collection time per unit of forest fuelwood, forest stock and distance of the house from the forestland. A possible explanation for this is that greater scarcity motivates the households to increase fuelwood collection from the forest and hence labour allocation to maintain a safe reserve so that they are able to cope with the risk when the times are even harder. Membership in forest protection committees has a negative influence on fuelwood collection and labour allocation which again goes against our expectations. This indicates that members of the committee are aware of the forest rules and therefore control fuelwood collection with an intention to conserve the forest rather than taking part in indiscriminate extraction. Increase in the trees on private land reduces collection of forest fuelwood and labour allocation and increases the likelihood of private energy consumption. However the effects on the first two dependent variables are insignificant and that on the latter is significantly positive but negligible. This indicates that the chances of substitution between fuels are very low. Same direction of change is observed in these three dependent variables with an increase in the level of education of the household head implicating that households with more educated heads have higher job prospects which are more remunerative and therefore curtail on fuelwood collection considering it to be an inferior activity. Moreover, education enhances their awareness of the negative impacts of forest over-extraction persuading them to replace forest fuelwood by private energy.

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