Forest Policy when Some Households Collect and Others Purchase Fuelwood

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Abstract

Subsistence households are a leading source of deforestation and their consumption of fuelwood, in particular, is important in many developing countries. Yet the empirical economic examinations of fuelwood consumption are sparse, particularly for rural areas where the deforestation occurs, and we would argue that forest policy is often designed without a good understanding of the potential responses of subsistence households to the new policy. This paper addresses these issues with household evidence from Nepal. It estimates household consumption and production of fuelwood. It finds significant distinctions with respect to responsiveness to market or resource oriented policies between households that collect fuelwood and households that also participate in the market. The obvious conclusion is that development agencies should consider fuelwood consumption and production distinctions in the local subsistence markets before they decide to promote, for example, improved stoves or other fuelwood substitutes and kerosene price supports, or seedlings and technical forestry assistance. Ill-advised policy choices will waste resources and fail to achieve the full desired effect on deforestation.

Keywords: Deforestation, econometric model, forest policy, fuelwood consumption.

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Introduction

Subsistence households are a leading source of deforestation and their consumption of fuelwood, in particular, is important in many developing countries. General discussions of household forestry activities feature the importance of basic resource distinctions (inventory levels and property rights) and gender distinctions (women as collectors and users), and recognize that household fuelwood oppor-

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tunities include both market participation and collection by household members. Yet the economic importance of these distinctions is relatively unexamined.[1]

The objective of this paper is to examine the distinction between the market and collection opportunities. The distinction is important for fuelwood, as well as for many other forest-based consumption goods in subsistence economies (*e.g.*, forage, fodder, fruits and nuts). Limited markets exist in most subsistence economies and all households could participate in these markets. Their decisions whether or not to participate depend on household labor opportunities. For some households, the market price of fuelwood, for example, is too great. The opportunity cost of household labor is relatively low and these households prefer to collect their fuelwood. The labor opportunities for other households are greater, and those households prefer to use their labor for alternative productive activities, and prefer to purchase some of their fuelwood.

The purchase-collection distinction is important for policy because policies intended to control deforestation generally target either the resource stock (*e.g.*, harvest restrictions, community forestry projects) or the market (*e.g.*, commercial cutting licenses and shipment controls affecting market supply, price supports for fuelwood substitutes). Wise policy choice depends on the relative purchase and collection elasticities, and the ease with which purchasing households switch to collecting, or collecting households switch to the market. Information about either market or collection responsiveness alone may mislead policy. The purchase-collection distinction is important for technical economic analysis because it implies two demand regimes over the range of quantities consumed.

This paper examines the purchase-collection distinction for agricultural households in Nepal's tarai. Fuelwood is the primary energy source for these households. The tarai is Nepal's lower and warmer Gangetic plain. It was an

[1] The empirical economic analyses, to our knowledge, include: Bluffstone (1995); Amacher *et al*. (1992, 1993a, 1993b), Scheer (1995), and Hyde *et al*. (1995) for resource distinctions; and Kumer & Hotchkiss (1988) and Amacher *et al*. (1993a) for gender distinctions. The sociology and anthropology literature is better developed, of course, and the economic literature for *urban* fuel consumption is also better developed.

underpopulated jungle until malaria control in the 1960s permitted human immigration and deforestation for agricultural land conversion. It still contains a small standing forest inventory, and it remains a source of fuelwood for local consumption as well as for the urban centers of Nepal's mid-hill region. Nevertheless, the tarai's forest stock is declining as the region becomes Nepal's most important source of agricultural production. Many tarai households collect fuelwood, and some also rely on market purchase.

Our analysis begins with a model of the utility maximizing household. We derive the household demand and supply functions, and then estimate them from household data. Some households choose — according to household preferences and labor opportunities — to collect and purchase fuelwood. Others choose to collect only. A switching regression accommodates both alternatives. We apply the econometric evidence from the switching regression to examine the effectiveness of Pigouvian taxes and other efficient policy options for forestry under the alternative conditions of household behavior.

The Household Model

Consider a representative household that maximizes a quasi-concave utility function dependent on the consumption of fuelwood and other goods. The household may either collect or purchase its fuelwood. (Generally, only a few specializing households sell fuelwood.) Hired labor is available for other household and farm activities, but Nepali households use their own labor for fuelwood collection, perhaps due to desires to increase savings, perhaps because fuelwood collection is a joint activity with another primary product like childcare (Amacher *et al.*, 1993a). The household budget determines an upper limit for fuelwood purchases.

More formally, the household maximizes its utility from fuelwood consumption by solving:

$$\begin{aligned} V(p,I;\Omega) = \mathrm{Max}_{F,X,L}\ & U(F,X,T-L;\Omega) \\ \text{s. t.} \quad & X + p_f F_p = M \end{aligned} \tag{1}$$

where $V(\cdot)$ is the household's indirect utility function, p is a vector of market prices, I is household income, and Ω is a vector of exogenous household characteristics. $U(\cdot)$ is household utility, and F and X are fuelwood and all other goods, respectively. T is total household time, L is household labor (time) used for fuelwood collection, and p_f is the market price of fuelwood. The income term M in the budget constraint accumulates all other exogenous household income.[2] This budget constraint is a cash constraint because the collection activity involves no financial transaction. (The household neither sells fuelwood, nor hires labor for fuelwood collection.) The price of X is one. Collected and purchased fuelwood, F_c and F_p, are perfect substitutes in consumption. Therefore, $F = F_c + F_p$.

The production function for collected fuelwood is concave in its arguments

$$F_c = C(L, R, A) \tag{2}$$

where R and A are measures of the resource stock and its accessibility respectively.

This model can be used to assess, first, the household's choice between collecting or purchasing fuelwood and, then, household fuelwood demand and supply under these alternative choices. The household chooses purchased fuelwood, labor allocated to fuelwood collection, and the consumption of residues and other goods according to the first order conditions:

$$\partial U / \partial F_p = \lambda p_f \tag{3}$$

$$-\frac{\partial U}{\partial L} + \frac{\partial U}{\partial F}\frac{\partial C}{\partial L} = 0 \tag{4}$$

$$\partial U / \partial X = \lambda \tag{5}$$

where λ is the marginal utility of income.

[2] Exogenous income M includes cash income and the value of production from other household subsistence activities. This formulation permits us to focus on the fuelwood activity. Data limitations prevent both a more complete specification of other household activities, and the subsequent derivation of the substitutions between fuelwood and these other activities.

Conditions (3) and (4), for F_p and F_c, together determine total household fuelwood consumption F. Since collected and purchased fuelwood are perfect substitutes in consumption, these conditions can be used to show that households both collect and purchase fuelwood when

$$\frac{\partial U/\partial L}{\lambda} \geq p_f \frac{\partial C}{\partial L} \tag{6a}$$

or when the ratio of the marginal disutility of labor used in collecting to the marginal utility of income is at least equal to the marginal value of money saved by collecting rather than purchasing. The comparative statics show that fuelwood collection increases as fuelwood prices increase and, as the cost of collecting fuelwood increases, labor allocated to collecting decreases and market fuelwood purchases increase. Thus, while collected and purchased fuelwood are perfect substitutes in consumption, they are imperfect substitutes in production.

Alternatively, households collect all their fuelwood, and decline to participate in the fuelwood market, when condition (3) is a strict inequality but condition (4) is a strict equality.

$$L > 0, \quad F_p = 0 \quad \Rightarrow \quad \frac{\partial U/\partial L}{\lambda} < p_f \frac{\partial C}{\partial L} \tag{6b}$$

When prices or the marginal product of collection are sufficiently high, eq. (6b) replaces eq. (6a), and all household fuelwood consumption becomes a product of the collection activity.

Consider the policy implications of this household behavior. Resource policies typically focus on either prices or the resource stock. A Pigouvian tax demonstrates the effect of a price policy. Imposing a tax, τF_p, on fuelwood purchases would revise eq. (6b) such that

$$L > 0, \quad F_p = 0 \quad \Rightarrow \quad \frac{\partial U/\partial L}{\lambda} < \left(p_f + \tau\right) \frac{\partial C}{\partial L} \tag{7}$$

The likelihood that a household only collects increases with the tax because the RHS of (7) increases — although total household fuelwood consumption may either increase or decrease, depending on the income, substitution and stock effects. We will investigate the relative strengths of these three effects in our empirical analysis.

EMPIRICAL MODEL

Eqs. (2) and (4)–(6) suggest the empirical specification to estimate

$$\begin{aligned} F = F_c + F_p = P\left(p_f, w, R, A; \Omega; \varepsilon_p\right) \quad &\text{if} \quad MRS^* \geq MP_L \\ F_c = C\left(p_f, w, R, A; \Omega; \varepsilon_c\right) \quad &\text{if} \quad MRS^* \geq MP_L \end{aligned} \tag{8}$$

$$L = L\left(p_f, w, R, A; \Omega; \varepsilon_L\right) \tag{9}$$

$$F^s = S\left(p_f, w, R, A; \Omega; \varepsilon_s\right) \tag{10}$$

$$X = X\left(p_f, w, R, A; \Omega; \varepsilon_x\right) \tag{11}$$

where w is the implicit wage for fuelwood collection and the ε_i are errors, and F^s represents the market supply of fuelwood. [The MRS and MP_L are the left-hand- and right-hand-sides, respectively, of conditions (6a) and (6b).] Eq. (8) represents fuelwood consumption, where household choices are defined through eqs. (6a) and (6b). It reflects the combination of market and household labor characteristics at which households change consumption regimes from collecting all of their fuelwood to purchasing some of it. Eq. (9) explains labor supply for fuelwood collection, the empirical equivalent of eq. (4). Eq. (10) defines the fuelwood supply function, and eq. (11) is the demand function for all other goods, the empirical equivalent of eq. (5). We can use the budget constraint to eliminate eq. (11). The exogenous variables are resource characteristics and household demographic characteristics, while the endogenous variables are prices, wages, fuelwood quantities and labor (total household expenditure of time for fuelwood collection).

The functional forms for these equations depend on the prior functional forms for the utility and production functions. Under the assumptions of a Stone-Geary utility function and a Cobb-Douglas production function, the production function becomes a log-log equation; the fuelwood consumption expenditure and labor supply for fuelwood collection equations become linear; and the fuelwood collection supply equation becomes log-log. This supply equation is obtained by applying Hotelling's Lemma to the profit function for fuelwood collection, conditional on the household allocation of labor for this activity (e.g., see Thorton, 1994).

This structural model contains five econometric problems: behavioral differences in households, unobserved household wages, non-separability of household production and consumption, identification, and heteroskedasticity. We will address each in turn. We anticipate behavioral differences between households that purchase and collect and households that only collect. Switching regressions (SR) accommodate this problem by incorporating a consumption shift at the price/quantity point where household behavior changes. We can examine the statistical significance of the demand shift predicted by the SR, as evidence of household behavioral differences and the appropriateness of the SR.[3]

The wage term in eqs. (8)−(10) is unobserved but implicit in household utility maximization. The household wage, or labor opportunity, depends on household preferences. Household labor preferences, however, are "nonseparable" from household preferences in production. This means that the resource stock and access variables, as well as prices and wages must be explanatory variables in all equations.[4] It also means that the unobserved wage variable must be estimated with an instrumental variable method. Thornton

[3] Switching regressions have been used, for example, to explain shifts from dryland to irrigated agriculture in response to changing prices and wages. Maddala (1983) discusses several cases where they are appropriate. These include cases where decisions based on individual preferences affect characterizations of demand or supply.

[4] Singh *et al.* (1986) explain household behavioral models, separability, and the econometric resolution of the non-separability problem.

(1994) and Jacoby (1993) suggest that a suitable estimate can be obtained by first estimating the production function [eq. (2)], and then using its estimated marginal product of labor in place of the wage term in eqs. (8)–(10). The production function itself must be estimated with a 2SLS procedure because production is a function of the endogenous labor variable.

The structural linkage of household consumption and production also suggests a 2SLS procedure for estimating eqs. (8)–(10). The first stage uses all exogenous variables to predict the endogenous variables. The second stage uses the predicted endogenous variables in an OLS estimation. We can protect against under-identification by insuring that each estimated equation includes at least as many excluded exogenous variables as endogenous variables in the equation, minus one. Altering the choices of demographic variables from one equation to another will allow us to satisfy this condition. Finally, family size, a demographic variable, can be used to correct for potential heteroskedasticity in the second stage equations.

DATA AND RESULTS

The data for our analysis were collected by students from Nepal's Institute of Forestry but under our guidance. Our survey focused on household fuelwood production and consumption over the month of the Desain holiday (October) in 1988. It includes a random collection of 286 rural households distributed across the breadth of Nepal's tarai region. The data are complete and uncensored with the exception that some households collect fuelwood but do not purchase it in the market. Other households both collect and purchase. Table 1 provides a list of our independent variables.

The Production Function and the Shadow Wage

Table 2 shows our production results. The equation test statistic is satisfactory and all independent variables in the production function have the anticipated signs. Fuelwood collection time is the standard labor term and livestock ownership is a proxy for the standard capital term. Livestock is a good proxy since more livestock indicates more draft animals, and draft animals are the household's most

Table 1. List of Variables.

Variable	Definition
	Exogenous Variables
Land	Household land ownership in hectares, a proxy for household income or wealth
*FArea**	Forest land area in the district, in thousands of hectares
*SArea**	Scrub forest land area in the district, in thousands of hectares
*FVol**	Standing forest volume in the district, in thousands of m^3
DRoad	Distance in km. from household to the nearest road (in the tarai)
DTown	Distance in km. from household to the nearest village
FS	Household family size
AU	Animal units, the number of livestock (goats, sheep, cows) owned by a household
Ethnic	Indicator of higher (Brahmin) household ethnic class
*DPop**	District population in thousands
CT	Total household collection time for fuelwood in hours per month
IS	Household possession of improved stoves, a technological substitute for fuelwood
	Endogenous Variables
WHat	The estimated shadow wage
PF	Fuelwood price in Nepali rupees per kg.
FP	Fuelwood purchased in kg.
FC	Fuelwood collected in kg.

* These four measures are from the 1991 Census of Nepal or the forest survey office of the Ministry of Forests and Soil Conservation. Remaining measures are from our survey.

valuable agricultural capital. Forest area and distance are measures of the resource stock. Greater distances to roads and towns mean less market access for the household, and probably less human access to the forest resource; therefore, less pressure on the resource and greater collection per household.

TABLE 2. HOUSEHOLD FUELWOOD PRODUCTION

INDEPENDENT VARIABLES[A]	COEFFICIENTS[B]
Constant	28.0 (1.52)
CT, total household collection time (+)	20.7^{***} (3.29)
AU, livestock (+)	18.2 (0.39)
FArea, forest Area (+)	0.570×10^{-4} (0.90)
DRoad (+)	0.0163 (0.27)
DTown (+)	0.0328 (0.76)
FS, family size (+)	0.0535 (0.12)
Land (?)	−27.3 (−0.61)
DPop, district population (?)	$-0.847 \times 10^{-4\,**}$ (−2.04)
log of likelihood function	−1379
degrees of freedom	277

[A] Anticipated sign in parenthesis.

[B] 2SLS estimates in log-log form. Assymptotic t ratios in parentheses. ***, **, and * imply statistical significance at the one, five, and ten percent levels, respectively.

The remaining variables are demographic characteristics. Larger families means both more labor for the collection activity and more consumption. Land holdings may be an indicator of household wealth, or a measure of the private resource stock. Greater wealth may induce households to rely more on market purchase rather than on their own collection. The negative sign on the land coefficient suggests that this wealth effect apparently dominates in our production function. The district is the local political jurisdiction (comparable to a US county). The negative sign on district population probably indicates that congestion, or more competition for the open access forest resource, means less collection per household.

The critical collection time variable is significant at the 99 percent level. It is the source of our estimated marginal products of labor for use in subsequent estimations. The mean marginal product of labor is 2.45 bhari (headload) or approximately 61.25 kg./hr.

Fuelwood Consumption, Labor Supply, and Fuelwood (Collection) Supply

Table 3 reports our empirical results for total household fuelwood consumption, labor supply for fuelwood collection, and the household supply of collected fuelwood. The first two columns report the switching regression results for fuelwood consumption, first for households that both collect and purchase, then for households that only collect. Twelve of the coefficients have expected signs, including the important price and wage coefficients and all coefficients in the collect and purchase regime. (The coefficients with unexpected signs are statistically insignificant.) We can reject the comparability of each consumption regime with the other at the 99 percent level — and, thereby, confirm the expectation of behavioral differences between the two classes of fuelwood consuming households.

Households are more likely to convert to pure collection as the fuelwood price increases, and households that collect only are more responsive to their implicit wages for fuelwood collection. Family size, therefore the number of potential fuelwood collectors in a household, and reduced market access both predict greater consumption for households that collect only. On the other hand, greater household wealth (as indicated by the land ownership proxy) indicates greater fuelwood consumption, but only for households that are wealthy enough to participate in the market.

The equations for the supply of collected fuelwood and for household labor supply for the collection activity are also satisfactory. Eight of twenty coefficients have the expected signs, and the important price and implicit wage coefficients continue their patterns of statistical significance. Apparently, better-off households, households that are nearer large resource stocks, and households that own improved stoves (a technological substitute for fuelwood) are more able to divert their labor to other non-fuelwood

TABLE 3. HOUSEHOLD FUELWOOD CONSUMPTION, LABOR SUPPLY, AND FUELWOOD (COLLECTION) SUPPLY.

INDEPENDENT VARIABLES	FUELWOOD CONSUMPTION (SWITCHING REGRESSION)[A]				LABOR SUPPLY FOR FUELWOOD COLLECTION[A]		SUPPLY OF COLLECTED FUELWOOD[B]	
		Collect/Purchase		*Collect Only*				
Constant		−28.7		−56.9		−55.8***		.225
		(−0.35)		(−1.14)		(−3.16)		(0.09)
PF	(−)	−71.6	(+)	33.5	(+)	65.2***	(+)	1.10
		(−1.52)		(1.25)		(3.31)		(1.53)
		[−.27]		[0.19]				
WHat	(+)	4.38***	(+)	6.45***	(+)	20.9***	(+)	2.55***
		(9.91)		(17.30)		(5.66)		(4.73)
		[0.34]		[0.44]				
Land	(+)	2.40**	(+)	−1.43	(−)	−.249	(+)	−.225
		(1.74)		(−1.40)		(−.94)		(−0.70)
		[0.17]		[−0.11]				
IS	(−)	−39.1	(−)	1.44	(−)	−.524		
		(−1.30)		(0.07)		(−0.10)		
FS	(+)	4.12**	(+)	5.87***	(+)	−.132	(+)	.284
		(1.90)		(3.66)		(−0.34)		(1.16)
FArea	(+)	$.145\times10^{-2\,***}$	(+)	$.105\times10^{-2\,***}$			(+)	−.371**
		(4.66)		(6.75)				(−1.74)
		[1.70]		[1.18]				
FVol					(?)	$-.115\times10^{-2\,*}$		
						(−1.66)		
SArea	(+)	$.122\times10^{-2}$	(+)	$-.334\times10^{-3}$				
		(0.26)		(−0.08)				
DTown	(?)	.209	(+)	.720***	(+)	.0109	(+)	−.0470
		(1.31)		(8.25)		(.34)		(−0.53)
		[0.13]		[0.65]				
DRoad							(+)	.0112
								(0.11)
Ethnic							(−)	−.015
								(−1.40)
AU					(?)	.562***		
						(2.59)		
DPop	(?)	$.48\times10^{-3\,**}$	(?)	$.129\times10^{-3}$	(?)	$.248\times10^{-4}$	(?)	.261***
		(2.85)		(1.43)		(0.82)		(2.70)
Log likelihood fn		−2107				−1411		−560
Degrees of freedom		264				276		276

Parenthetical expressions are expected signs and assymptotic t ratios. ***, **, and * indicate statistical significance at the one, five, and ten percent levels, respectively. Bracketed expressions are consumption elasticities calculated at the mean.

[A] Linear 2SLS regressions [B] Log-log 2SLS regression activities. The volume of collected fuelwood increases as the market price and the implicit wage increase. Only forest area and one measure of access (*DTown*) in the fuelwood supply equation have unexplained signs, and the latter is statistically insignificant.

Policy Implications

Table 3 also reports the critical consumption elasticities (in brackets). They stress the behavioral differences between the two classes of fuelwood consumers, and they imply the policy importance of recognizing these differences — particularly with respect to market variables and measures of resource availability. Most clearly, households that collect and purchase are more price responsive than households that only collect. As fuelwood prices rise, households that collect and purchase decrease consumption and some of them withdraw from the market to begin collecting their total consumption of fuelwood. Both classes of households are more responsive to changes in the marginal products of their labor than to changes in the market, but households that only collect are relatively more responsive.[5]

Contrary to our expectations, households that only collect are not as responsive to the usual measure of forest stock (*FArea*) as households that also participate in the market. (The difference, however, is small.) Households that only collect are relatively much more responsive, however, to market access. Reduced market access also suggests less human pressure on the local forest resource. Access may be a more reliable predictor of resource availability in our case because our measure of the stock refers to an entire geographic region while our measure of access refers to each specific household observation. This would suggest that collector households are also relatively more responsive than purchaser households to resource access, and that collector households are relatively more responsive to resource access than to the level of resource stocks.

[5] The distinction is also important for practicing economists who may mistakenly suggest that the opportunity cost of collection time is a good measure of fuelwood value. In fact, evidence suggests that collection time overestimates fuelwood value, perhaps because collection time is one input to more than one joint product (Amacher *et al.*, 1993a).

In Nepal's tarai, neither class of households is highly market responsive (elasticities less than one for both prices and the estimated wage), and both classes are more responsive to changes in resource availability (stock elasticities greater than one and access elasticities greater than the price and wage elasticities for those households most likely to collect). These are reasonable findings for a good like fuelwood that consumes a small share of household endowments of cash or labor opportunity. They argue that public policies focusing on resource stocks and market access will have greater impacts in Nepal's tarai than policies that affect fuelwood markets more directly. Therefore, forest conservation and economic development activities that increase resource stocks by, for example, distributing seedlings, sharing information on tree growth, or improving property rights to existing stocks will be more successful than, for example, controlling market fuelwood prices directly, introducing fuel substitutes, or controlling market harvests through systems of licensing or government road inspections to restrict fuelwood flows to the markets. Furthermore, fuelwood policies that enhance local access to resource stocks also have better distributive effects as they induce relatively greater responses in the generally less-well-off households that collect only.

These specific results may not be true for fuelwood consumers universally, but they do point to the importance of distinguishing between collecting and purchasing households, and between resource and market effects, when designing policy.[6] Most subsistence communities include households that only collect fuelwood and other households that collect but also participate in local fuelwood markets. Northwestern Pakistan, northeastern Thailand, Ethiopia, Lao, Malawi, the Philippine uplands, south India, and Bangladesh, in our own experience, all fit this characterization and all support development projects or policies aimed at fuelwood conservation and deforestation control. It is not apparent to us that anyone inquired about local measures of economic resource scarcity or substitution, or local production and consumption patterns before

[6] Of course, given some statistical insignificance of the estimates, our policy statements in this section must be weighed with caution.

choosing the locations of emphases of these forestry activities when they were new. Our intuition tells us that many local subsistence households would be more responsive to forestry activities designed with reference to the distinctions between local resource and market effects. Furthermore, since measures of physical resource stock generally reflect economic value only poorly, then our intuition also tells us that consumer household access to the resource is important and that subsistence households would be more responsive to forestry activities designed with this distinction in mind as well.

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