The Environmental Impact of Poverty: Evidence from Firewood Collection in Rural Nepal

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Abstract

In the context of collection of firewood by rural households in Nepal, we test the *poverty-environment hypothesis (PEH)* which asserts the necessity of reducing poverty to ease pressure on forests. Household data from the World Bank 1995-95 Living Standards Measurement Survey for 215 Nepal villages do not provide evidence for PEH after controlling for household characteristics, village fixed effects, and censoring of firewood collections. Cross-village variations in collections are consistent with the intra-village results, and the existence of social conformity norms within villages. The results imply growth in living standards *per se* would not reduce collections. The point estimates in fact suggest the opposite. Collections could however be substantially reduced by spread of primary education and growth of nonfarm employment opportunities.

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1 Introduction

Policy discussions concerning environmental degradation in poor countries are dominated by the *poverty-environment hypothesis (PEH)*, which asserts that poverty alleviation is a precondition for environmental sustainability. Initially proposed by the 1987 Brundtland Commission and the Asian Development Bank (Jalal (1993)), it has received prime attention by academics and policy experts recently (Barbier (1997a, 1998, 1999), Duraiappah (1998), Jalal (1993), Lele (1991), Lopez (1998), Maler (1998)). The PEH is based on the notion that the poor rely more than others on common property resources (CPRs) such as open access forests, owing to a variety of reasons: a lower shadow cost of labor (the main source of access cost), a lower preference for cleaner but more expensive fuel substitutes, and credit constraints that prevent shift to less forest-intensive occupations, livestock and land practices. The possibility of a reverse causation from deforestation to poverty (owing to dependence of the poor on forest products) has also been frequently discussed in this literature, which might cause an environmental poverty trap. In addition, higher poverty or inequality may inhibit informal collective action within rural communities that regulates CPR use (Baland and Platteau (1996, 1997), Bardhan and Dayton-Johnson (1997)). According to the PEH, therefore, halting environmental degradation requires the reduction of poverty, via growth or redistributive public policies. The related literature on environmental Kuznets curves (Barbier (1997b), Grossman and Krueger (1995), Yandle, Vijayaraghavan and Bhattarai (2002)) based mainly on macro evidence also suggests that increases in living standards beyond some threshold will ease pressures on environmental resources.

Yet there has been a remarkable paucity of empirical tests of the PEH. A large body of literature documents the significant CPR reliance of the poor, relative to their own consumption (e.g., see the survey by Beck and Nesmith (2001), or various studies of Jodha (1986, 1992, 1995)). This is not sufficient to justify the PEH, which requires an assessment of how CPR use varies with living standards (i.e., of the poor relative to the non-poor). Much of the empirical literature concerning CPRs utilizes cross-sectional data at the level of villages or communities (e.g., Agrawal and Yadama (1997), Bardhan (2000), Varughese (2000)). Cross-village evidence is subject to potential problems of endogeneity, whereby poverty may be a consequence of deforestation, or of other unobserved factors (such as topography or soil conditions) that affect both the level of local poverty and the state of neighbouring forests.

Since most of these channels of reverse causation arise at the village level, variations in CPR use across households within the same village are more revealing. This is the strategy pursued in this paper, which relates intravillage variations in firewood collection to differences in consumption levels of households, controlling for village fixed effects. We use data from the 1995-96 Living Standards Measurement Survey (LSMS) in 215 villages in Nepal, a country where deforestation has assumed alarming proportions in the past few decades.[6] A complicating feature is that about 30% of the households in the sample collected no firewood at all, relying instead on other sources of energy. This necessitates the use of a fixed effects estimation procedure which allows for endogenous censoring, for which we rely on the semiparametric estimator proposed by Honore (1992). Additional complicating features incorporated in the estimation procedure are truncation in collection times due to its unobservability for noncollectors, and potential endogeneity of consumption levels as well.

We find no evidence in favor of the PEH. The raw data show (see Figure 1) that for households who collect firewood, collections do not decrease with living standards

[6]Deforestation in Nepal has been held principally responsible for a significant drop in major foodgrain yields since the 1960s (estimated at 35% between 1960 and 1980), and for the disastrous 1988 monsoon floods in Bangladesh, owing to resulting soil erosion (Metz (1991)). The soil erosion has caused increased landslides and vulnerability to earthquakes. Households in Nepal (particularly women) devoted significantly higher time to collect firewood, resulting in reduced farm effort and time devoted to child-rearing (Kumar and Hotchkiss (1988).

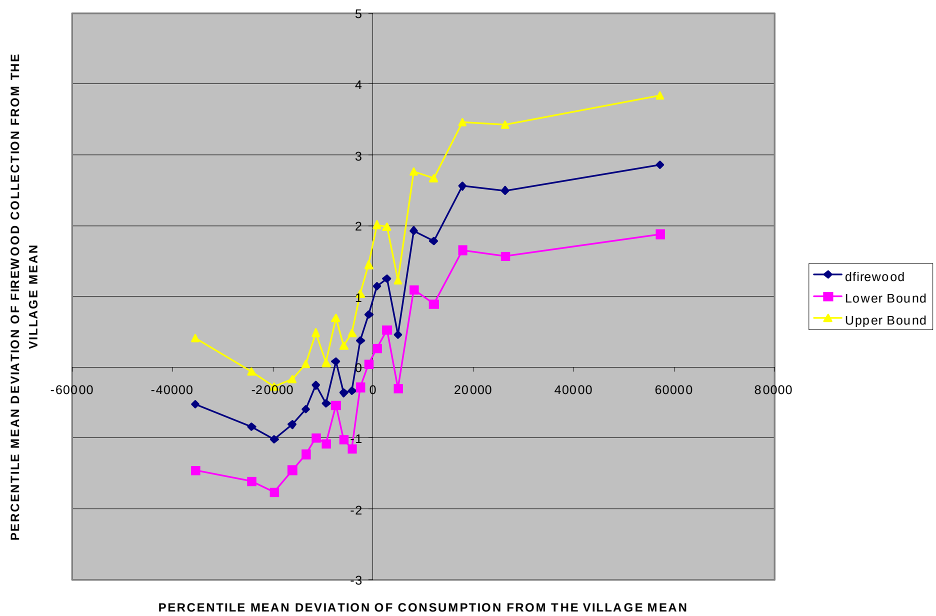

Figure 1: Firewood Collection-Consumption Plot, Deviations from Village Mean

of households within the same village. Figure 1 plots the 95% confidence band for mean deviation of firewood collection from the village mean for twenty different percentile groups (each corresponding to a five percentile group) against corresponding deviations in consumption levels of these different groups. It shows evidence against the PEH: the poorest groups collect significantly less (with a difference of more than three bharis, which substantially exceeds the width of the 95% confidence band).

Our model decomposes the effect of living standards on firewood collection into effects of varying consumption levels (the pure 'wealth' effect) and of varying shadow cost of collection time. After controlling for village fixed effects and a variety of household characteristics (demographics, location, education, farm and non-farm assets, collection time), we find that the effect of consumption on collections was statistically insignificant. The estimated relationship shows collections were increasing and concave in consumption over the range observed in the sample. The absence of a negative wealth effect is unsurprising given absence of affordable fuel substitutes for most households in Nepal, which forces wealthier households to meet rising energy needs by collecting more firewood. We also find no evidence of a higher shadow cost of collection time among wealthier households, possibly owing to the ability of these households to rely increasingly on children, servants and extended family members for collecting firewood. On the other hand we find that higher levels of education and nonfarm employment signficantly reduce collections by raising the shadow cost of their time.

Residuals from the household regression provide an estimate of the village effects, which are subsequently regressed against village characteristics (using a random effect tobit to correct for censoring effects).[7] Under the hypothesis of interdependence of collection activities of different households within a village induced by village norms (social sanctions or peer effects), relevant village characteristics include aggregates of relevant household characteristics. In particular, the 'reflection property' induced by norms imply that the village fixed effects will be more sensitive with respect to (village aggregates of) relevant household characteristics than in the household-level regression. This is precisely what we find: the pattern of signs and significances at the village level regression mirror (and magnify) those at the household level. At the village level, collection levels are significantly positively correlated with average consumption, population, proximity to the forest and to (dirt) roads, and negatively

[7]In principle, both coefficients with respect to household and village characteristics can be estimated in one step. We avoided this for a number of reasons. First the household level results with village fixed effects provide the most direct test of the PEH. The validity of this test is not contingent on the nature of the village effects or consistent estimation of the latter. Getting instruments for village effects is much harder than that for households, so the two step procedure helps generate reliable estimates at the household level. We can use a fixed effects estimator at the household level, in contrast to a random effects estimator at the village level. Moreover, a simultaneous one step estimation shrinks the sample size considerably owing to severe compounding of problems of missing values at the village level.

with average household size and levels of education. We also find a significant positive effect of higher caste fragmentation within the village, presumably reflecting the adverse impact on informal collective action regulating firewood collection. There is no significant correlation with the fraction of households in forest user groups (created by Nepal's scheme for handing back management of forests to user communities).

These results suggest that appropriate policy responses to limiting firewood collection in Nepal are quite distinct from what the PEH would suggest. Rises in living standards that eliminate poverty would not significantly ease the pressure on forests (and could very well increase them), unless they are accompanied by widening access to modern fuel substitutes, higher education and growth of nonfarm employment opportunities. Simulations of the estimated model reveal that rising consumption levels by themselves would result in approximately equiproportionate increase in collection activities. But simultaneous achievement of universal primary education would neutralize the effect of upto 40% growth in consumption. Forest sustainability in Nepal thus necessitates closer attention to qualitative characteristics of the process of development, i.e., to shifts in occupation and educational patterns, and availability of modern fuel substitutes.

These results for rural Nepal are contrasted with those for Pakistan and India obtained respectively by Chaudhuri and Pfaff (2002) and Foster and Rosenzweig (2002). Chaudhuri and Pfaff find an inverse U-shaped relation between firewood use and incomes in the 1991 Pakistan household data (which combines rural and urban households), while Foster and Rosenzweig find a small (but statistically significant) negative effect in cross-sectional Indian rural household data from 1982. The differences between these countries may arise from different access to alternative fuels, education levels and levels of per capita income. For instance, the switch to modern fuels in Pakistan identified by Chaudhuri and Pfaff occurs particularly among urban households, where fuel substitutes are more easily available than rural areas. Even within rural households there was significant use of kerosene and electricity in cooking: the proportion of rural households using kerosene and electricity for cooking in Pakistan was 90% and 58% respectively, compared with 3% and 1.4% in Nepal. Educational levels in rural Pakistan were substantially above those in Nepal: e.g., the average years of schooling of household heads in the rural Pakistan sample was 6.3 years, in comparison to 1.87 years in the rural Nepal sample. Moreover, our estimated quadratic relationship between collections and consumption levels is downward sloping over ranges of high consumption beyond those observed in the Nepal sample. This suggests that the environmental Kuznets curve may apply in Nepal, but it is still operating on the upward sloping segment.

Other literature on firewood collection in Nepal stresses the role of nonagricultural labor markets and forest property rights in specific parts of the country. Amacher, Hyde and Kanel (1996) and Bluffstone (1995) discuss evidence concerning significant elasticities of labor supply and fuelwood collection activities of Nepalese households with respect to shadow wages in the low lying *terai* region, though not at higher altitudes. Edmonds (2002) finds a robust 11–14% reduction in firewood collection at the household level with respect to formation of forest user groups in the LSMS data for the Arun Valley (which covers three districts in Eastern Nepal that came under the Nepal-United Kingdom Community Forestry Project, out of 75 districts in all of Nepal). In contrast our results which apply to the entire LSMS sample finds negligible effects of shadow wages or forest user groups. In a related paper, Edmonds (2000) finds that the effect of the forest user groups varies substantially with the type and source of external development assistance in different parts of Nepal, and that it was implemented most effectively in the Arun Valley. The difference between our results and existing literature may therefore owe to differences in geographical area covered.

The underlying model is presented in Section 2. The nature of the data and related features of the Nepalese environment is discussed in Section 3. Household level results are presented in Section 4, and the village level results in 5. Section 6 concludes.

2 Model

Household i in village v has a utility function

$$U_{iv} = u(F_{iv}, q_{iv}, l_{iv}, hs_{iv}) - \xi(F_{iv} - \frac{F_v}{n_v}) \tag{1}$$

where F_{iv} denotes firewood used by the household, q_{iv} denotes quantity of other goods consumed, l_{iv} denotes leisure time (including time devoted to household tasks), hs_{iv} denotes family size and composition. ξ denotes the effect of village norms, an increasing and convex function of deviation of household consumption from the village average $\frac{F_v}{n_v}$, where $F_v \equiv \sum_i F_{iv}$ is aggregate firewood used in the village, and n_v is the number of households in the village. This can represent a pure 'peer' effect in consumption, or the present value of utility deviations in future periods resulting from sanctions imposed by the rest of the village for excessive current consumption.

Each household takes as given village prices of all other goods (denoted p_v), and firewood consumption of the rest of the village. Then given a level of expenditure E_{iv} net of pecuniary costs of firewood, household size and composition hs_{iv}, the household has the following indirect utility function

$$W_{iv} = w(F_{iv}, l_{iv}; p_v, E_{iv}, hs_{iv}) - \xi(F_{iv} - \frac{F_v}{n_v}) \tag{2}$$

where $w(.)$ is obtained by maximizing $u(.)$ subject to $p_v.q_{iv} \leq E_{iv}$. We assume that this indirect utility function is strictly concave with respect to F_{iv}.

Owing to data limitations we will ignore the possibility of firewood markets within the village. About one-tenths of the Nepal LSMS sample households purchase some firewood: the smallness of this sample makes it difficult to study purchase-sale decisions with any accuracy. We therefore assume that firewood used must be entirely collected by the household itself.

The cost of using firewood includes two components: (i) the time it takes to collect, valued at the shadow cost of this time to the household, and (ii) any fees that the household may have to pay to a forest guard. The shadow cost of time depends on the household's assets, employment opportunities, and allocation of its labor across different occupations and tasks. We explain below how these are determined.

The time T_{iv} taken to collect one unit of firewood by household i in village v depends (besides the household's own location within the village) on the proximity and density of the forest stock. In turn the latter depends on the historical forest endowment FS_v of the village, and on extraction activities of village residents besides other factors collectively captured by T:

$$T_{iv} = T + \delta(FS_v - F_v) + \epsilon_{iv} \tag{3}$$

Here FS_v denotes the historical forest stock endowment of the village, and ϵ_{iv} an idiosyncratic mean-zero household deviation from the village average time which depends on the exact location of the household. Equation (3) incorporates an extraction externality across households: greater extraction by others causes the forest stock to dwindle, increasing the time required to extract by any given household.

The opportunity cost of time taken to collect firewood depends on alternative uses of the household's time. The household earns income from allocating family labor across different occupations: $j = 1, 2, 3, 4, 5$ respectively denote (1) self-employment in agriculture, (2) wage labor in agriculture, (3) wage labor in non-agriculture, (4) self-employment in nonagriculture, and (5) self-employment in livestock grazing and fodder collection. The latter activity is complementary with collecting firewood. For simplicity we shall assume that firewood collection and livestock grazing are perfectly complementary activities. Besides the above activities, time is allocated to firewood collection $t_{iv} \equiv T_{iv}F_{iv}$ and leisure l_{iv}. The total stock of labor of the household is measured by family size (the number of adults plus half the number of children in adult equivalent units); for now we shall denote this by hs_{iv}. The labor allocated to occupation j is denoted s_{iv}^{j}, so the time allocation constraint is (given $s_{iv}^{5} \equiv t_{iv}$:)

$$hs_{iv} = \sum_{j=1}^{4} s_{iv}^{j} + l_{iv} + t_{iv} \tag{4}$$

The budget constraint is given by

$$E_{iv} = \; y^1(s_{iv}^1; \theta_{iv}^1, e_{iv}, p_v, a_v) + w_v^2 s_{iv}^2 + w_v^3 s_{iv}^3 + y^4(s_{iv}^4; \theta_{iv}^4, e_{iv}, p_v, a_v) + y^5(t_{iv}; \theta_{iv}^5, p_v, a_v) - c_v^f F_{iv} \tag{5}$$

where y^1, y^4, y^5 are the returns to agriculture, nonfarm business, and livestock activity, which respectively depend (apart from labor allocated) on land (θ_{iv}^1), education e_{iv}, nonfarm business assets (θ_{iv}^4) and livestock (θ_{iv}^5) owned by the household. The returns to wage labor are given by the corresponding wage rates w_v^2, w_v^3 in neighboring agricultural and nonagricultural labor markets. The returns to various self-employed activities also depend on village infrastructure a_v and prices p_v. Finally, c_v^f denotes the expected fee that the household has to pay a forest guard for collecting one unit of firewood. This depends on the nature of forest property rights and their enforcement (including probability of the collection being monitored and the fees that have to be paid in that event), either by the government or the community itself.

Household i in village v has a given set of characteristics $\theta_{iv} \equiv (hs_{iv}, \theta_{iv}^1, e_{iv}, \theta_{iv}^4, \theta_{iv}^5)$, collection time per unit of firewood T_{iv}, and takes as given village variables $\frac{F_v}{n_v}, W_v \equiv (p_v, w_v^2, w_v^3, a_v, c_v^f)$. It selects firewood collection F_{iv} and labor allocation $l_{iv}, s_{iv}^j, j = 1, \ldots, 5$ to maximize utility (2) subject to constraints (4) and (5). It is convenient to break down this optimization problem into two stages: for a given level of firewood collection (which determines time devoted to livestock grazing and collecting firewood) the household first decides how to allocate its remaining time $L_{iv} \equiv hs_{iv} - T_{iv}F_{iv}$ between non-livestock earning activities and leisure. This helps define the utility and cost of collecting firewood. Then at the second step it selects how much firewood to collect by equating associated marginal cost and utility.

Suppose the household collects a positive amount of firewood. Then its best response to the collection activities of others equates marginal cost MC_{iv} with marginal utility MU_{iv}. The marginal cost (based on the solution to the first-stage optimization problem) can be expressed in monetary units as

$$MC_{iv} = c^l_{iv} T_{iv} + c^f_v \tag{6}$$

where

$$c^l_{iv} \equiv [\frac{\frac{\partial w}{\partial l_{iv}}}{\frac{\partial w}{\partial E_{iv}}}] \frac{\partial l_{iv}}{\partial L_{iv}} + \sum_{j=1}^{4} \frac{\partial y^j}{\partial s^j_{iv}} \frac{\partial s^j_{iv}}{\partial L_{iv}} - \frac{\partial y^5}{\partial s^5_{iv}} \tag{7}$$

denotes the shadow cost of time of the household. Similarly the marginal utility of collection measured in monetary units is

$$\begin{aligned} MU_{iv} &= \frac{1}{\frac{\partial w}{\partial E_{iv}}} [\frac{\partial w(F_{iv}; p_v, hs_{iv}, l_{iv}, E_{iv})}{\partial F_{iv}} - \xi'(F_{iv} - \frac{F_v}{n_v})] \\ &= \alpha_0 + \alpha_1 F_{iv} + \alpha_{21} E_{iv} + \alpha_{22} {E_{iv}}^2 + \alpha_3 hs_{iv} \\ &\quad + \alpha_4 (F_{iv} - \frac{F_v}{n_v}) + \alpha^{'}_v + \eta_{iv} \end{aligned} \tag{8}$$

upon taking a linear approximation with zero-mean error η_{iv}, and where $\alpha^{'}_v$ represents effects of village variables such as prices. This expression drops leisure l_{iv}, under the assumption of separability in utility between firewood collection and leisure. We expect α_1, α_4 to be negative, and α_3 to be positive. The wealth effect is represented by coefficients α_{21}, α_{22} of household consumption and its square. We include a quadratic term here to allow for possible nonlinearity of the wealth effect. Normally one would expect it to be positive, since the demand for fuel would increase with wealth. On the other hand, firewood may be an inferior good among wealthier households, who might be inclined to switch towards higher quality and more expensive sources of fuel such as kerosene, gas or electricity.

If we treat the shadow cost of time c^l_{iv} as independent of the level of collection and a function of the household's characteristics, and therefore a household characteristic itself, we obtain the household's best response function by equating expressions (6) and (8) for marginal cost and marginal utility respectively:

$$\begin{aligned} F_{iv} &= \frac{1}{-\alpha_1 - \alpha_4}[\alpha_0 + \alpha_{21}E_{iv} + \alpha_{22}{E_{iv}}^2 + \alpha_3 hs_{iv} - \alpha_4 \frac{F_v}{n_v} + \alpha_v^{'} - c_v^f + c_{iv}^l T_{iv} + \eta_{iv}] \\ &= \gamma_1 + \gamma_{21}E_{iv} + \gamma_{22}{E_{iv}}^2 + \gamma_3 hs_{iv} + \gamma_4 \frac{F_v}{n_v} + \gamma_5 c_{iv}^l T_{iv} + \alpha_v + e_{iv}^1 \end{aligned} \quad (9)$$

where e_{iv}^1 is a zero-mean error. The theory then predicts $\gamma_3, \gamma_4 > 0$, $\gamma_5 < 0$, while the signs of γ_{21}, γ_{22} are ambiguous, depending on the nature of wealth effects. According to the PEH, poorer households collect more firewood because of negative wealth effects (γ_{21}, γ_{22} are negative), and because they are subject to a lower shadow cost of collection time (γ_5 is negative). Equation (9) can be estimated from the data with village fixed effects.

The problem with estimating (9) is the difficulty of obtaining a measure of the shadow cost of time from the data. Wage rates cannot be used since there may be subtantial unemployment and surplus labor in these villages, and the majority of households are exclusively self-employed. Besides, the above derivation of the best response equation assumes that the shadow cost of time is independent of the amount of time devoted to collection. Since the collection times involved are quite considerable on average, this assumption is questionable.

It is better therefore to treat the shadow cost as endogenous, and relate it to household and village characteristics. Since households always consume positive leisure, the shadow cost of time equals the marginal utility of leisure:

$$c_{iv}^l = \frac{\partial w(F_{iv}, L_{iv} - \sum_j s_{iv}^j; p_v, E_{iv}, hs_{iv})}{\partial L_{iv}} \quad (10)$$

Given separability of utility between leisure and and other arguments entering the utility function, the marginal utility of leisure is a function only of the quantity of leisure $L_{iv} - \sum_{j=1}^4 s_{iv}^j$. Taking a linear approximation, we obtain

$$c_{iv}^l = \kappa_1 + \kappa_2[hs_{iv} - F_{iv}T_{iv} - \sum_{j=1}^4 s_{iv}^j] + e_{iv}' \quad (11)$$

where e'_{iv} denotes a zero mean approximation error, and $\kappa_1 > 0, \kappa_2 < 0$. The right-hand-side of (11) includes time allocated to farm and nonfarm income earning activities which are determined simultaneously with firewood collection. In the reduced form version of the model the allocated times will be a function of household characteristics: a household with more farm or nonfarm assets would devote more time to those activities (under the plausible assumption of complementarity between asset ownership and returns from the corresponding occupation), thus reducing time available for collecting firewood, grazing livestock and other household tasks. Conversely a household with more livestock would *ceteris paribus* allocate less time to farm and nonfarm earning activities, leaving more time for grazing livestock and collecting firewood. We can then express the shadow cost as a function of time collecting firewood and household characteristics:

$$c^l_{iv} = \delta_1 + \delta_3 hs_{iv} + \delta_4 F_{iv} T_{iv} + \delta_5 \theta_{iv} + V_v + e''_{iv} \tag{12}$$

where the coefficient δ_5 is expected to be positive with respect to farm or nonfarm assets, and negative with respect to livestock owned. In the event of nonseparability between leisure and consumption (wherein rising consumption raises the value of leisure), this equation generalizes to:

$$c^l_{iv} = \delta_1 + \delta_2 E_{iv} + \delta_3 hs_{iv} + \delta_4 F_{iv} T_{iv} + \delta_5 \theta_{iv} + V_v + e''_{iv} \tag{13}$$

where $\delta_2 > 0$.

The marginal cost of collection for the household then reduces to

$$\begin{aligned} MC_{iv} &= c^f_v + T_{iv}[\delta_1 + \delta_2 E_{iv} + \delta_3 hs_{iv} + \delta_4 F_{iv} T_{iv} + \delta_5 \theta_{iv} + V_v + e''_{iv}] \\ &= c^f_v + \delta_1 T_{iv} + \delta_4 T^2_{iv} F_{iv} + \delta_2 E_{iv} T_{iv} + \delta_3 hs_{iv} T_{iv} + \delta_5 \theta_{iv} T_{iv} + \delta_6 V_v T_{iv} + e^3_{iv}. \end{aligned} \tag{14}$$

Equating with marginal utility, we obtain the best response equation

$$\begin{aligned} F_{iv} &= \frac{1}{-\alpha_1 - \alpha_4 + \delta_4 T^2_{iv}}[\alpha_0 + \alpha_{21} E_{iv} + \alpha_{22} E^2_{iv} + \alpha_3 hs_{iv} + \alpha_4 \frac{F_v}{n_v} + \alpha'_v - c^f_v - \delta_0 T_{iv} \\ &\quad -\delta_2 E_{iv} T_{iv} - \delta_3 hs_{iv} T_{iv} - \delta_5 \theta_{iv} T_{iv} - \delta_6 V_v T_{iv} - e^3_{iv}] \end{aligned} \tag{15}$$

Taking a linear approximation to $\frac{1}{-\alpha_1-\alpha_4+\delta_4 T_{iv}^2}$, the best response can be represented as

$$\begin{aligned} F_{iv} &= \beta_0+\beta_{21}E_{iv}+\beta_{22}E_{iv}^2+\beta_3 hs_{iv}+\beta_5 T_{iv}+\beta_6 T_{iv}^2+\beta_7 E_{iv}T_{iv}+\beta_8\theta_{iv}T_{iv} \\ &\quad +(\beta_4\frac{F_v}{n_v}+W_v)+e_{iv}^4 \end{aligned} \tag{16}$$

where W_v is a village effect that incorporates common village influences on utility (such as climate) and cost (such as collection charges) of firewood, and the error term e_{iv}^4 absorbs all the ignored interaction and higher order terms resulting from the linear approximation.[8]

If we now drop the assumption of a positive interior level of collection, we can replace (16) by its censored version:

$$F_{iv}=\max[0,\beta_0+\beta_{21}E_{iv}+\beta_{22}E_{iv}^2+\beta_3 hs_{iv}+\beta_5 T_{iv}+\beta_6 T_{iv}^2+\beta_7 E_{iv}T_{iv}+\beta_8\theta_{iv}T_{iv}+Y_v+e_{iv}^4] \tag{17}$$

where $Y_v \equiv \beta_4\frac{F_v}{n_v}+W_v$.[9] In (17) the interaction term $E_{iv}T_{iv}$ arises only in case of nonseparability between consumption and leisure. The pure wealth effects are identified by the coefficients of consumption. Accordingly (as explained further in Section 4) we shall use a measure of permanent consumption for E_{iv}, which will be predicted on the basis of household assets and other characteristics. Hence the interaction effects (β_8) between asset ownership and collection time can be interpreted as the effect of assets on the shadow cost of time, since the direct effect of assets on consumption is already incorporated in the regression. PEH now corresponds to the hypothesis that the wealth effects are negative ($\beta_{21},\beta_{22}<0$), and that the

[8]In particular, we have dropped the interaction between collection time and household size or composition, which may be believed to be important *a priori*. These interaction effects turned out to be insignificant, so we dropped them to minimize collinearity with the household stock/composition levels.

[9]Here we exploit the fact that indirect utility of the household is concave with respect to firewood, while the marginal cost is increasing.

interaction of consumption or asset ownership and firewood collection time is negative ($\beta_7, \beta_8 < 0$).

3 Description of Data

3.1 Descriptive Statistics

Tables 1 and 2 provide descriptive statistics concerning household and village characteristics respectively. The World Bank Living Standards Measurement Survey (LSMS)for Nepal covers 274 wards, of which 215 are rural. We use only the data for the rural wards, involving 2712 households, who were interviewed concerning their production and consumption activities for the year 1995-96. Nearly one third of the sample did not collect firewood at all. On average a household collected 5.8 *bharis* or bundles of firewood a month. For those who collected per bhari collection time was over five hours on average, with significant variation across households (a coefficient of variation approximately one). The average elevation above sea level was around 3100 feet, with a standard deviation of 3100 feet, implying considerable variation in elevation, going up to about 17,000 feet. Many of these villages were spread out, resulting in an average within-village standard deviation of collection time of 1.8 hours. Households mentioned adults as the principal collectors of firewood, and females somewhat more important than males in this respect (average number of adults collecting per household was 1.56, of which female adults accounted for 0.94). 77% of the households collected firewood from a government or community forest, with the remaining households collecting either from their own lands or other sources (such as from roadsides).

The mean annual consumption for a household was Rs. 35,000. Given the average household size was 4.4 (in adult equivalent units), corresponding to a per capita consumption of approximately $250. The average poverty gap (relative to a poverty line of \$1 per day per capita) was 14%, while that relative to \$1.50 per day was 43%, indicating high levels of poverty. 13% of the households were headed by women. The majority were engaged in self-employed agricultural activities and livestock rearing. Principal assets consisted of cultivated land, livestock and nonfarm business assets. Education levels were low: 70% of heads of households had no education. In terms of religion, the households were predominantly Hindu: only 6% were Buddhists, 4% Muslim and 1% belonged to other religions. 35% belonged to upper castes (*brahmin* or *chhetry*), 28% to middle castes (*magar, thuru, newar, tamang, rai, gurung, limbu*), 13% to lower castes (*kami, damai and surki*). Hence there was greater ethnic than religious fragmentation. 11% of the households reported migrating into the village for non-economic reasons within the current and previous generation.

The villages were fairly remote from modern transport and communication: the average distance to dirt roads, markets or agricultural extension services took more than 3 hours to traverse (frequently on foot), with paved roads 8 hours away. They were also fairly disaster prone, with 56% of the villages having experienced a natural disaster within the previous five years.

Table 3 shows that wood fuel was the main source of energy for cooking and heating for 74% of the households (the other leading sources being cowdung (18%) and leaves or straw (6%)). Only 3% of the households used kerosene or gas as the primary source of cooking or heating fuel, and a comparably miniscule proportion used kerosene/gas stoves. Hence modern fuel sources are conspicuous by their absence. However, kerosene was used by 83% households as the principal source of lighting, so there was wide access to kerosene. The low use of kerosene or gas may owe to limited availability or high cost of kerosene/gas, of kerosene/gas stoves, or persistence of traditional cooking and heating practices.

The villages vary considerably with regard to elevation, which ranges from 190 to 17000 feet above sea level. The low lying *terai* region, usually defined by an elevation of up to 1000 ft above sea level, has experienced the greatest deforestation since the

1950s, owing to successful malaria control, development of nonfarm opportunities and rapid in-migration from higher non-*terai* villages (Metz (1991)). Table 4 shows the principal characteristics of these two regions in the LSMS sample. Approximately 60% of the households in the sample are from the non-*terai* region. The two regions do not differ significantly with respect to average consumption, household size or education standards. However, two-thirds of *terai* households do not collect firewood at all (compared with 8% in the non-terai), and the remaining collect one-third of what non-terai households do. This is despite the fact that collection times are approximately the same in both regions. The two regions do differ significantly with regard to occupational structure: despite a higher value of farm land relative to nonfarm assets, a higher fraction of household employment in the *terai* is in the non-farm sector.

The government of Nepal introduced a community forestry scheme in 1993, handing over forest areas to be managed by local communities. The 1993 Forest Act defined 'forest user groups' as autonomous corporate bodies that were assigned control over designated forest areas 'in perpetuity'. The user groups draw up a five year plan to manage, protect and share forest produce. The use of forest products is subject to regulations and charges; the groups hire forest guards to monitor compliance. The groups also plan and implement reforestation schemes.[10] Implementation of the scheme has been gradual, so many communities are yet to form forest user groups. Edmonds (2000) argues that exogenous factors such as proximity to towns and district capitals have determined the selection of communities where forest user groups have been created. In our sample, the average (across villages) of the fraction of households within a village who reported collecting from a community forest was 11%, and 43%

[10] Over 8000 user groups had been created by 1999, with the government handing over over 600,000 hectares to groups in 74 out of 75 districts. See Mahapatra (2000). The government plans eventually to hand over 3.5 million hectares to local communities in this way, representing 61% of all forest land in Nepal.

of the villages had at least one such household in the sample. This is used as a proxy for membership in a forest user group, since the LSMS questionnaire did not include a direct question about membership. We do not include this information among the set of household characteristics owing to the possible measurement error it entails, besides the potential endogeneity of this variable.[11]

[11] Accounts of the creation of these groups (Mahapatra (2000)) indicate they followed investigations by the government of forest dependence on a household-by-household basis, which implies that membership could be the effect of high levels of firewood collection. Since membership is a dummy variable it proved difficult to predict on the basis of household instruments.

TABLE 1: Household Characteristics: Descriptive Statistics

Variable	Number of Observations	Number of Zeroes	Mean	Standard Deviation	Minimum	Maximum
Firewood Collected (bharis/month)	2670	807	5.78	5.76	0	35
Collection Time (hrs per bhari)	1858	0	5.04	2.74	0.17	14
Annual Consumption Expenditure (Rs.)	2712	0	35309	27630	2869	445936
Value of Cultivable Land (Rs.)	2348	685	145736	588266	0	17500000
Value of Non-Farm Business Assets (Rs.)	2712	2260	7940	73167	0	25000
Fraction Labor Non-Agriculture (self-employed)	2673	2071	0.08	0.21	0	1
Fraction Wage Labor Agriculture	2673	1590	0.15	0.25	0	1
Fraction Wage Labor Non-Agriculture	2673	1705	0.11	0.20	0	1
Number of Cows Owned	2439	241	3.72	3.12	0	27
Household Size (Adult Equiv.)	2712	25	4.41	2.06	0.00	20.4
Years Schooling Household Head	2712	1912	1.87	3.39	0	17
Female-Headed Household	2712	2361	0.13	0.34	0	1
Fraction Children	2712	741	0.26	0.20	0	0.8
Fraction Prime-Age Males	2712	133	0.35	0.18	0	1
Fraction Prime-Age Females	2712	69	0.35	0.17	0	1
Fraction Old Men	2712	2423	0.02	0.08	0	1
Upper Caste (Brahmin-Chetry)	2710	1756	0.35	.48	0	1
Middle Caste (Magar-Lumbu)	2710	1962	0.28	0.45	0	1
Low Caste	2710	2477	0.09	0.28	0	1
Hindu	2710	357	0.87	0.34	0	1
Buddhist	2710	2535	0.06	0.25	0	1
Muslim	2710	2614	0.04	0.18	0	1
Other Non-Hindu Religion	2710	2680	0.01	0.10	0	1
Migration into Village for Non-Economic Reasons	2712	2420	0.11	0.31	0	1
Time to Market	2640	14	6.4	18.07	0	168
Time to Shop	2566	64	0.93	4.45	0	144

TABLE 2: Village Characteristics: Descriptive Statistics

Variable	Number of Observations	Number of Zeroes	Mean	Standard Deviation	Minimum	Maximum
Mean Consumption (Rs)	215	0	35623	13783	1147	99124
Gini Consumption	215	0	0.30	0.09	0.09	0.66
Average Poverty Gap ($1 per day)	215	19	0.13	0.11	0.00	0.48
Population	215	0	797	889	42	5875
Mean Household Size	215	0	4.39	0.72	2.76	6.64
Fraction in Forest User Group	215	125	.11	.19	0	1
Gini Landownership	208	0	0.64	0.14	0.27	0.92
Ethnic Fragmentation	215	52	0.33	0.24	0	0.74
Religious Fragmentation	215	119	0.14	0.19	0	0.75
Mean Collection Time (hrs/bhari)	184	0	5.27	2.44	0.50	12.86
Standard Deviation Collection Time	179	0	1.78	0.88	0.00	5.95
Average Cows Owned	215	0	3.62	1.67	0.4	9.10
Years Schooling Household Head	215	17	1.88	1.46	0	7.08
Proportion Female-Headed Household	215	55	0.13	0.12	0	0.58
Time to Dirt Road (hrs.)	208	0	6.20	12.99	0.02	84.00
Time to Market Center (hrs.)	215	0	4.21	7.43	0.10	61.09
Time to Krishi Center (hrs.)	215	0	3.21	4.23	0.13	25.62
Time to Paved Road (hrs.)	205	0	8.03	13.05	0.06	84.00
Kerosene/Gas Stove Access (dummy)	215	187	0.13	0.34	0	1
Average Agricultural Yield (Rs. million/acre)	208	0	0.16	0.22	0.01	1.69
Elevation above sea level (Km)	215	0	0.94	0.94	0.058	5.29
Latitude (deg.)	215	0	27.69	0.84	26.42	29.75
Longitude (deg.)	215	0	84.68	2.13	80.25	88.08
Natural Disaster Dummy	196	87	0.56	0.50	0	1

TABLE 3: Fuel Sources

Percent households using as	wood	cowdung	leaves and crop residues	kerosene	others: electricity,gas, biogas, coal,...
primary source	72.8	18.4	6.1	1.7	0.9
secondary source	5.8	8.9	26.1	1.4	0.5

TABLE 4: Characteristics of Terai and Non-Terai Regions

	Terai	Non-terai
Number of Households	1054	1658
Mean Household Consumption	34527 (27437)	35805 (27748)
Mean Household Size	4.61 (2.25)	4.27 (1.96)
Mean Value of Cultivated land	222528 (711717)	107242 (511314)
Mean Value of Non-Farm Assets	5768 (39375)	9320 (88139)
Mean Years Schooling of Household Head	2 (3.44)	1.78 (3.35)
Mean Number of Cows	2.98 (2.94)	4.14 (3.14)
Mean % of Time Given to Non-Farm Occupations	22 (29)	17 (26)
Proportion of Households not Collecting	0.65	0.08
Mean Collection per Collecting Household	2.37 (4.04)	7.96 (5.64)
Mean Collection Time per Collecting Household	5.0 (3.07)	5.03 (2.67)
Standard deviations in parentheses		

4 Household-Level Intra-Village Estimation

4.1 Estimation Procedure

The best response equation (17) includes censoring and village fixed effects. The nonlinearity of the model precludes estimating the model in first differences which washes out the village fixed effects. Accordingly we rely on the semiparametric estimator proposed by Honore (1992) for this purpose. We call it PANTOB. The problem with implementing this estimator are twofold.

First, households that do not collect any firewood do not report collection times (that they would have encountered had they chosen to collect). Thus incorporation of such households in the estimating sample (necessary to avoid sample selection biases) requires us to use a proxy for their collection times. Since information concerning other characteristics of these households are available, we can predict collection times based on observed household characteristics. Accordingly we postulate

$$T_{iv} = \lambda_1 \theta_{iv} + \lambda_2 Z_{iv} + \lambda_v + \eta^1_{iv} \tag{18}$$

where θ_{iv} represents vector of household assets owned, and Z_{iv} a vector of instruments uncorrelated with the error term in the firewood equation (17). It is plausible that proximity to the forest will be correlated with ownership of farm and nonfarm business assets in ways that depend on the precise topography of these villages (e.g., those with nonfarm business assets may be located closer to market areas which may be on the opposite side of the village from where the forest lie, so such households may incur higher collection times). For instruments Z_{iv} we include ethnicity and migratory status which do not affect utility or cost of collecting firewood *per se* after controlling for levels of consumption, asset ownership and household size that enter the firewood equation. But they may affect location patterns owing to patterns of ethnic segregation of housing within the village. The fixed effect in (18) captures the village level effects arising from historical forest stock and proximity, and steady state extraction activities of villagers that were incorporated in (3).

To estimate the coefficients of (18), we encounter the endogenous sample selection problem: the dependent variable is observed only for those who collect firewood, so the sample is probably biased in favor of those with low collection times. The selection equation is provided by the firewood equation: collection times are observed for those with

$$\begin{aligned} F^*_{iv} \quad \equiv \quad & \beta_0 + \beta_{21} E_{iv} + \beta_{22} E^2_{iv} + \beta_3 hs_{iv} + \beta_5 T_{iv} \\ & + \beta_6 T^2_{iv} + \beta_7 E_{iv} T_{iv} + \beta_8 \theta_{iv} T_{iv} + (\beta_4 \frac{F_v}{n_v} + W_v) + e^4_{iv} \\ > 0. \end{aligned} \tag{19}$$

This is a sample selection model with fixed effects, for which we use the estimator proposed by Kyriazidou (1997). In this procedure, a first round set of consistent estimates of λ_1 and λ_2 is obtained from a conditional logit for the sample selection model implied by equations (18) and (19). At the second stage a weighted least squares panel regression of (18) is estimated, where the weights vary with the estimated degree of sample selection bias and are constructed on the basis of the first round estimates of λ_1, λ_2.

The estimated λ_1, λ_2 coefficients can then be used to obtain a consistent estimate of the village fixed effect λ_v for those villages containing at least one collector:

$$\hat{\lambda}_v = \frac{\sum_{i \in C_v} (T_{iv} - \hat{\lambda}_1 \theta_{iv} - \hat{\lambda}_2 Z_{iv})}{NC_v} \tag{20}$$

where C_v denotes the set of collecting households in village v, and NC_v the number of such households. We then predict the collection times for noncollectors using the estimated coefficients of (18) and their observed characteristics θ_{iv}, Z_{iv}. These households can be included in estimation of (17) with their predicted collection time proxying for their actual collection time.

The second problem with using PANTOB is that it assumes all right-hand-side explanatory variables are exogenous. As explained above, the exogeneity of consumption is a dubious assumption in a context with so much self-employment. So we use a set of instruments I_{iv} to predict consumption, apart from asset ownership and household demographics:

$$E_{iv} = \nu_1 + \nu_2\theta_{iv} + \nu_3 hs_{iv} + \nu_4 I_{iv} + \nu_v + \eta^2_{iv}. \tag{21}$$

This amounts to using a measure of permanent consumption in the firewood regression, since unsystematic transitory shocks belong to the error term of the above equation. The instrument set includes ethnic status, age of head of household, education and occupation of the father of the head, and value of land inherited by the head, which are plausibly uncorrelated with the residual in the firewood collection equation (17) after controlling for the households consumption and other characteristics that enter it.[12] When consumption is instrumented in this way, it modifies the sample selection equation as a function of the household's characteristics (i.e., when combined with (18)) so this necessitates re-estimating the coefficients of (18). Following this, we obtain the coefficients of the collection equation (17) upon applying PANTOB to the data using the predicted collection times for noncollectors (using the estimated coefficients of (18), and consumptions predicted by the estimated coefficients of (21). The PANTOB standard errors underestimate the true standard errors for not incorporating the fact that collection times and consumption levels are subject to prediction error. We therefore bootstrap in order to estimate the additional variability of PANTOB's estimates due to variability in the estimates of coefficients of (18) and (21).[13]

[12] Estimation of (21) is mercifully not subject to any censoring biases, and reveals ethnic status, parental literacy, occupation and age of the head to be significant determinants of consumption.

[13] In particular, let θ_2 denote the vector of estimates from PANTOB and θ_1 denote the vector of estimates prior to it. Then the variance of θ_2, denoted $V(\theta_2)$ can be decomposed as $E(V(\theta_2|\theta_1)) + V(E(\theta_2|\theta_1))$. PANTOB provides a consistent estimate of the first term. The sample analog of

Before presenting the estimation results, we note that Figure 1, displays a rising concave pattern with respect to consumption levels, which flattens out for the top half of the sample. It suggests that a quadratic term should suffice to pick up the nonlinearity of the wealth effect. Table 5 presents estimated coefficients of the panel household regressions with censoring. Version 1 excludes interaction between consumption and collection time, while Version 2 shows the effects of including this interaction. Version 3 corresponds to the case where consumption is treated as exogenous, and Version 4 where it is endogenous but the square of consumption is dropped. Implied elasticities and effects of one standard deviation changes in each variable on latent collections are shown for Version 1 in Table 6. Firewood collection is increasing and concave in consumption when it is treated as endogenous, though these coefficients are not statistically significant. The hypothesis of zero or positive wealth effects cannot be rejected: hence the evidence does not favor the PEH. Measurement error in permanent consumption is likely to bias the estimated coefficient downward, which reinforces this conclusion.

The estimated elasticity of collections with respect to consumption exceeds one at the bottom of the distribution, but becomes less than one at the median and above. Hence the reliance on firewood collections expressed as a proportion of consumption rises at the bottom end of the distribution, and falls thereafter. The latter is consistent with the numerous studies in Asia and Africa documenting that the ratio of CPR use to consumption is highest among the poor. Only in this sense it is true that the poor depend more than the nonpoor on firewood. Yet this does not imply that a reduction in poverty would reduce pressure on the forests, since a rise in consumption of the

the second term is obtained by bootstrapping. This procedure treats the data as constituting the population base, with samples of the same size drawn from it with replacement. The sampling scheme retained the panel structure of the original dataset, where villages were redrawn repeatedly. Estimates were computed with the drawn samples and used to compute measures of variability. Five hundred and fifty samples were drawn; the standard errors stabilized with respect to the number of samples drawn. For further details of this bootstrapping procedure see Efron and Tibshirani (1993).

poor would raise their collections in absolute terms. The relevant criterion is whether the elasticity is positive, not whether it is less than one. The latter fact is pertinent instead to the distributional impact of deforestation: a less than unit elastic demand for firewood implies that the (proportional) impact on the living standards of the poor of deforestation would be greater.

TABLE 5: Household Panel Latent Firewood Collection Determinants: Different Specifications

	Version 1	**Version 2**	**Version 3**	**Version 4**
Variable	Estimate (bootstr. std. err.)	Estimate (bootstr. std. err.)	Estimate (uncorrected std. err.)	Estimate (uncorrected std. error)
Consumption	77.71 (77.57)	59.62 (76.50)	34.35* (17.64)	48.96 (34.47)
Consumption Square	-249.96 (727.83)	-409.56 (646.02)	17.51 (77.77)	
Collection Time	-0.15 (0.31)	-0.43 (0.33)	-0.25 (0.29)	-0.17 (0.32)
Collection Time Square	0.02 (0.03)	0.02 (0.03)	0.02 (0.02)	0.02 (0.03)
Consumption* Collection Time		8.68 (5.91)	1.10 (3.24)	
Land Owned* Collection Time	-0.22 (0.15)	-0.24* (0.14)	-0.23* (0.14)	-0.22 (0.15)
Nonfarm Business Assets* Collection Time	-0.29* (0.16)	-0.36* (0.15)	-0.37** (0.18)	-0.29** (0.14)
Cows Owned* Collection Time	0.01 (0.01)	0.01 (0.01)	0.02* (0.01)	0.01 (0.01)
Years Schooling of Head* Collection Time	-0.03** (0.01)	-0.03* (0.01)	-0.02* (0.01)	-0.03** (0.01)
Household Size	0.95** (0.42)	0.88** (0.43)	0.93*** (0.30)	1.05** (0.42)
Household Size Square	-0.05 (0.03)	-0.04 (0.03)	0.03 (0.02)	-0.05 (0.03)
Fraction Children	-1.01 (3.56)	-1.14 (3.46)	-1.40 (3.27)	-1.11 (3.61)
Fraction Prime-Age Males	-0.45 (3.27)	-0.60 (3.17)	-0.73 (2.98)	-0.52 (3.31)
Fraction Prime-Age Females	0.88 (2.84)	0.73 (2.74)	0.62 (2.67)	0.79 (2.88)
Fraction Old Men	-0.25 (2.97)	-0.56 (2.93)	0.56 (2.77)	-0.07 (2.98)
Female Head	-0.15 (0.39)	-0.13 (0.38)	-0.15 (0.38)	-0.19 (0.38)
Time to Market	0.00 (0.01)	-0.00 (0.01)	0.00 (0.01)	0.00 (0.01)
Time to Shop	-0.03 (.02)	-0.02 (0.02)	-0.02 (0.02)	-0.03 (0.02)

Consumption instrumented except in Version 3
The * in the Variable column denotes interactions
No. of observations= 1427; p-value for chi-sq test for joint significance =0.00
*: significant at 10%, **: significant at 5%, ***: significant at 1%

TABLE 6: Household Panel Latent Firewood Collection Determinants: Estimated Elasticities Based on Version 1

Variable	Derivative (abs. t-value)	Elasticity at 30th percentile	Elasticity at Median	Elasticity at 75th percentile	Effect of one S.D. increase (95% CI =+/-)
Consumption (Rs. mill.)	62.97 (1.49)	1.42	0.37	0.25	1.66 (2.18)
Collection Time	0.01 (0.13)	-0.06	0.01	0.04	0.02
Land owned	-0.89 (0.59)	-0.00	-0.01	-0.01	-0.53 (0.68)
Nonfarm assets	-1.15 (1.78)	0.00	0.00	0.00	-0.09 (0.09)
Number of cows owned	0.04 (0.97)	0.09	0.03	0.02	0.14 (0.28)
Years Schooling Head	-0.12 (2.24)	0.00	0.00	-0.03	-0.39 (0.34)
Household Size	0.57 (2.53)	2.18	0.48	0.25	1.14 (0.89)
Fraction Children	-1.01 (0.28)	-0.14	-0.05	-0.04	-0.20 (1.38)
Fraction Prime-age Male	-0.44 (0.14)	-0.11	-0.03		-0.02 (1.14)
Fraction Prime-Age Female	0.88 (0.14)	0.22	0.06	0.04	0.14 (0.91)
Fraction Old Male	-0.25 (0.09)	0.00	0.00	0.00	-0.02 (0.43)
Time to Market	0.00 (0.07)	0.00	0.00	0.00	0.01 (0.34)
Time to Shop	-0.03 (1.20)	-0.00	-0.00	-0.00	-0.14 (0.22)

Derivatives and simulations are evaluated at the median which is less than the mean by censoring.

There is evidence of household economies of scale, with a coefficient less than unity. Apart from consumption and household size, the significant determinants of firewood collection are interactions with collection time of land, nonfarm assets owned, and education of head of household. These are both negative and significant. Since the regression already controls for the wealth effect of asset ownership via consumption, these interactions should be interpreted as effects of occupational structure rather than wealth. The signs of the estimated interactions are consistent with this interpretation: higher farm or nonfarm assets and hence lower livestock ownership shifts households away from livestock grazing and firewood collection activities. Household age and gender composition have the signs expected, but are insignificant. Owing to locational dispersion of the households within villages, we also included proximity to the nearest market area and to the nearest shop (which may affect access to fuel substitutes), but these turned out to be insignificant.

The other source of evidence against the PEH concerns its predictions concerning the shadow cost of collection time. The interaction of consumption with collection time is positive and insignificant. So there is no evidence that wealthier households have a higher shadow cost of collection time. Further evidence is provided in the Appendix. It also suggests that the shadow cost may not matter for collection activities. We explore possible reasons for this later in this section.

The effect of occupational structure on collections is further explored in Table 7, the first column of which replaces the interactions of collection time with different assets by its interaction solely with the fraction of household working hours in nonfarm occupations. This is negative and significant. Hence a greater reliance on nonfarm occupations significantly lowers shadow cost of collection time, presumably since such occupations require household members to work in neighboring urban or semi-urban locations located further away from the forest. The second column of Table 7 examines the determinants of reliance on nonfarm occupations. Households whose heads are more educated, male, and whose parents were also employed in nonfarm occupations tend to be more involved in nonfarm occupations.

Finally, to check that our results are not affected by aggregation of *terai* and non-*terai* households, we estimated version 1 in Table 5 for each group separately. Due to missing values, the regression sample for *terai* reduced to only 343 observations while that for non-*terai* reduced to 1084 observations. As seen in Table 4 censoring is much higher in the former. PANTOB was used for both the samples, parallel to Version 1 of Table 5. The results are reported in Table 8. Education turns out to be important in both regions. But the effect of occupational choice on collection differs according to whether land or business assets are more important (see Table 4). The other main difference between the regions is that collections in the terai do not vary with household size, and the *terai* exhibits a significant location effect. Similar to the pooled data, the estimated relationship with consumption is increasing and concave within both regions and statistically insignificant. In other words there is no evidence in any region in favour of the PEH. The same is true in the raw data as shown in Figure 2 and Figure 3. Hence our principal conclusions are unaffected when the firewood collection equation is estimated separately for the *terai* and non-*terai*.

TABLE 7: Role of Education and Nonfarm Employment

	Firewood Collection bharis per household (uncorrected s.e.)	Nonfarm Employment fraction of household working hours (uncorrected s.e.)
Consumption	37.87 (68.68)	
Consumption Square	9.60 (748.28)	
Collection Time	-0.05 (2.49)	
Collection Time Square	0.02 (0.29)	
Nonfarm Empl* Collection Time	-0.003* (0.001)	
Value of Land Owned		-4.14 (3.81)
Nonfarm Business Assets		47.13*** (15.37)
Number of Cows Owned		-2.01*** (0.43)
Years Schooling of Head		1.59*** (0.39)
Continued Next Page		

TABLE 7 continued

Household Size	1.02*** (0.42)	0.18 (1.49)
Household Size Square	-0.04 (0.02)	0.08 (0.11)
Fraction Children	-1.87 (1.35)	17.28 (16.79)
Fraction Prime-Age Males	-1.11 (1.34)	14.27 (16.93)
Fraction Prime-Age Females	0.12 (1.41)	-.03 (16.89)
Fraction Old Men	1.24 (2.23)	-15.73 (21.76)
Female Head	0.03 (0.38)	-17.17*** (5.12)
Time to Market	0.00 (0.01)	0.004 (0.04)
Time to Shop	-0.03 (.03)	-0.07 (0.25)
Literacy of Father of Head (dummy)		1.02 (2.82)
Father Self-employed Non-agric (dummy)		17.46*** (4.85)
Father Wage Labor Agri (dummy)		-3.26 (3.26)
Father Wage Labor Non-agri (dummy)		0.89 (4.48)
Age of Head		-0.09 (.08)
Migrant for non-economic reasons (dummy)		3.72 (4.42)
Upper caste (dummy)		-2.28 (3.34)
*: significant at 10%, **: significant at 5%, ***: significant at 1%		

TABLE 8: Household (Panel Latent) Firewood Regressions in Terai and non-Terai

	Terai	non-Terai
Variable	Estimate	Estimate
	(uncorr. std. err.)	(uncorr. std. err.)
Consumption	275.03	63.12
	(209.88)	(87.68)
Consumption	-2506.10	-115.57
Square	(2291.80)	(801.24)
Collection Time	-0.81	-0.02
	(0.61)	(0.35)
Collection Time	0.09	0.004
Square	(0.06)	(0.03)
Land Owned*	-0.54**	-0.11
Collection Time	(0.16)	(0.21)
Nonfarm Business Assets*	-4.77	-0.31**
Collection Time	(5.33)	(0.15)
Cows Owned*	-0.01	0.01
Collection Time	(0.02)	(0.01)
Years Schooling of Head*	-0.04*	-0.03*
Collection Time	(0.02)	(0.02)
Household Size	0.04	1.15**
	(0.01)	(0.44)
Household Size	-0.03	-0.05*
Square	(0.07)	(0.03)
Fraction Children	-3.97	-0.40
	(3.74)	(4.03)
Fraction Prime-Age	-2.88	0.39
Males	(3.98)	(3.71)
Fraction Prime-Age	1.32	0.85
Females	(4.24)	(3.18)
Fraction Old Men	-3.70	1.04
	(5.46)	(3.34)
Female Head	-2.30**	0.34
	(0.99)	(0.41)
Time to Market	0.67*	0.001
	(0.34)	(0.009)
Time to Shop	-1.27**	-0.02
	(0.54)	(0.02)
Number of observations	343	1084
*: significant at 10%, **: significant at 5%, ***: significant at 1%		

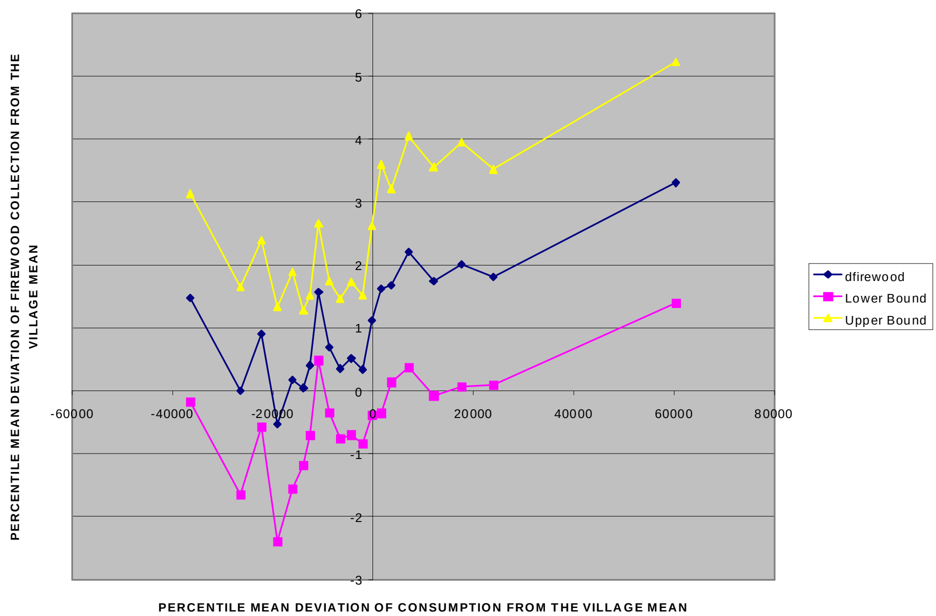

Figure 2: Collections-Consumption Relationship in Terai, Deviations from Village Mean

We return now to the question why the shadow cost of collection time does not rise with consumption standards. Underlying the PEH is the idea that wealthier households principally have higher productive (rather than unproductive) assets, implying a higher return on the time of these households allocated to the corresponding productive activities. However, this implies a higher shadow cost of collection time only under the additional hypothesis that devoting more time to productive activities cuts into time available for household tasks or leisure, and the marginal utility of the latter is diminishing over this range. If the household stock of labor is large enough relative to time devoted to productive activities, there can be enough 'slack' within the household that the marginal disutility of higher amounts of time devoted to productive activities does not cut into time available for household tasks. This may be so in a traditional rural society where children and extended family members live nearby can be called upon to help out with firewood collection and other household

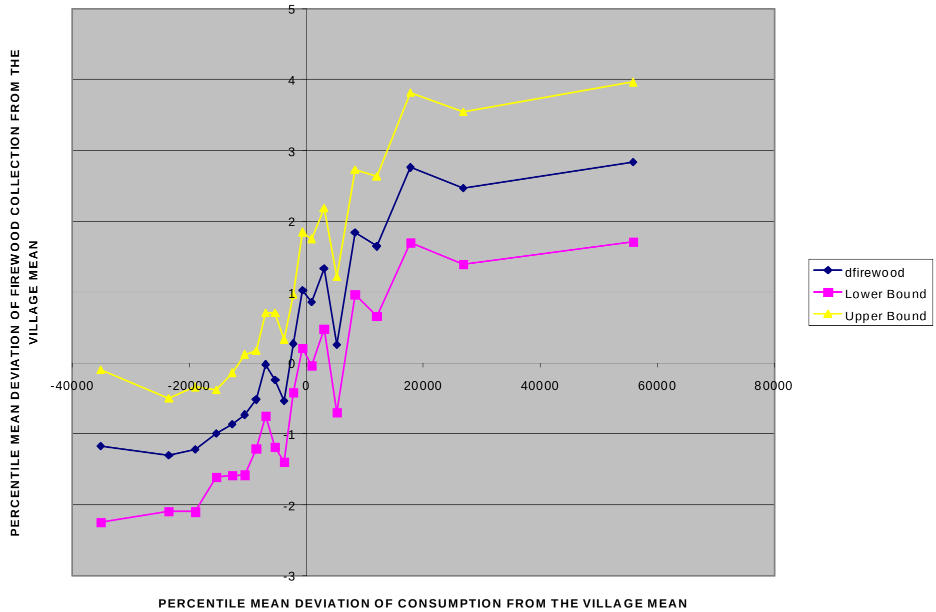

Figure 3: COLLECTIONS-CONSUMPTION RELATIONSHIP IN NON-TERAI, DEVIATIONS FROM VILLAGE MEAN

tasks.

The Nepal LSMS contains information about the collectors of firewood within the household. Table 9 presents this information for households classified into different per capita consumption quartiles. For each quartile it presents the per household reliance on different types of household members. Households in higher consumption quartiles rely less on the household head and more on the spouse of the head. A clearer picture of patterns of intrahousehold substitution of tasks among members is shown in Table 10, which partitions the sample into households of differing size (measured in adult equivalent units), and within each size class presents the same information across different quartiles of total (rather than per capita) consumption. As household size increases, there is a stronger tendency for wealthier households to switch reliance away from the household head towards children and others (primarily servants and extended family members).

TABLE 9: Collection Patterns across Different Household Members for different Per Capita Consumption Quartiles

Mean ratio of collectors to households (of following category)	Bottom Quartile	Second Quartile	Third Quartile	Top Quartile
Household head	0.63	0.59	0.58	0.55
Spouse	0.55	0.60	0.65	0.63
Children	0.70	0.66	0.63	0.59
Grandchildren	0.03	0.02	0.03	0.05
Others	0.38	0.36	0.31	0.34

TABLE 10:Collection Patterns across Different Household Members by Household Size and Consumption Quartiles

Mean ratio of collectors to households (of following category)	Bottom Quartile	Second Quartile	Third Quartile	Top Quartile
Effective Household Size not exceeding 3				
Household head	0.75	0.61	0.68	0.75
Spouse	0.39	0.58	0.62	0.78
Children	0.17	0.21	0.36	0.34
Grandchildren	0.01	0.00	0.08	0.03
Others	0.13	0.19	0.14	0.19
Effective Household Size between 3 and 5				
Household head	0.72	0.65	0.61	0.53
Spouse	0.64	0.65	0.73	0.64
Children	0.44	0.61	0.59	0.67
Grandchildren	0.01	0.02	0.03	0.04
Others	0.20	0.19	0.28	0.30
Effective Household Size between 5 and 7				
Household head	0.66	0.45	0.50	0.39
Spouse	0.47	0.56	0.69	0.63
Children	0.95	1.26	1.02	1.11
Grandchildren	0.05	0.07	0.02	0.09
Others	0.50	0.46	0.50	0.59
Effective Household Size between 7 and 9				
Household head	0.67	0.59	0.34	0.30
Spouse	0.67	0.53	0.41	0.54
Children	0.33	0.88	1.28	1.21
Grandchildren	0.00	0.12	0.03	0.05
Others	0.67	0.88	1.10	1.00

5 Village Effect Determinants

Equation (16) represents the best response of a household (ignoring censoring issues) to the collection activities of the rest of the village. Letting ω_{iv} denote the set of household characteristics that appear in this equation, and $\boldsymbol{\beta}$ the corresponding coefficient vector, we can represent this response equation more compactly as follows:

$$F_{iv} = [\beta_0 + \boldsymbol{\beta}.\omega_{iv} + W_v] + \beta_4 \frac{F_v}{n_v} + e^4_{iv}. \tag{22}$$

It is natural to expect that increases in the collection of others causes each household to collect more, i.e., β_4 is positive. This is inherent in the nature of peer effects and social sanctions that create pressures for conformity. Under the additional 'stability' condition that this slope is less than one, we can solve for the equilibrium collections in the village as a function of village average $\boldsymbol{\omega}_v$ of the relevant household characteristics:

$$\frac{F_v}{n_v} = \frac{1}{1-\beta_4}[\beta_0 + \boldsymbol{\beta}.\boldsymbol{\omega}_v + W_v]. \tag{23}$$

This expression shows that the response of village average collections with respect to the average of any relevant household characteristic will be a multiple of the corresponding coefficient in the household response equation. This is a consequence of the 'multiplier' effect induced by the social norms: a small change in a characteristic of one household that causes this household to collect more, induces other neighboring households to also collect more, which reflects back on the original household, creating a sequence of exponentially declining 'ripple' effects.

This multiplier property suggests a way of using a cross-village regression (23) to independently confirm results obtained from the intra-village household regression. For instance if collections are increasing (resp. decreasing) with respect to some characteristic at the household level, the same should be true for cross-village variations of corresponding village averages. However, this overlooks the possibility that the village effect W_v may also depend on village characteristics $\boldsymbol{\omega}_v$. Recall that the collection charge c^f_v enters the village effect W_v, and reflects the nature of forest management, and thus ultimately on the nature of collective action within the village community. Theories of collective action suggest the importance of population size, average living standards, preference heterogeneity concerning collective goods, social fragmentation and remoteness of the community from the outside world as important determinants (e.g., see the Symposium on Management of Local Commons in the *Journal of Economic Perspectives*, 1993). Hence there will be substantial overlap between averages of household-level determinants, and determinants of the extent of collective action. Other community-level determinants of household marginal utility and cost of firewood collection (which enter W_v) may include geography and remoteness, which may be correlated with consumption standards and forest proximity.

We therefore postulate that the determinants of the village effect W_v include elements of $\boldsymbol{\omega}_v$ such as average levels and inequality in consumption, and a variety of village level variables (represented by the vector $\boldsymbol{\phi}_v$) that potentially affect collective action and geography.

$$W_v = \sigma_0 + \boldsymbol{\sigma}_1 . \boldsymbol{\omega}_v + \boldsymbol{\sigma}_2 . \boldsymbol{\phi}_v + \varepsilon_v \tag{24}$$

The vector $\boldsymbol{\phi}_v$ includes: (i) population size and its square; (ii) landownership inequality; (iii) standard deviation of collection times within the village, which represents preference heterogeneity within the village with regard to firewood use, and the ability of residents to monitor each other's collection activities; (iv) ethnic fragmentation; (v) property rights over neighboring forests represented by membership in forest user groups; and (vi) geographical determinants of dependence on firewood (such as altitude and remoteness from roads and markets).

Combining (23) and (24), we obtain the following expression for village average collection levels:

$$\frac{F_v}{n_v} = \beta_0^{'} + [\boldsymbol{\sigma}_1 + \boldsymbol{\beta}^{'}] . \boldsymbol{\omega}_v + \boldsymbol{\sigma}_2^{'} . \boldsymbol{\phi}_v + \varepsilon_v^{'} \tag{25}$$

where primed variables are obtained from unprimed ones upon premultiplying by $\frac{1}{1-\beta_4}$. Cross-village variations in collections can thus be explained by variations in means of household-level characteristics $\boldsymbol{\omega}_v$ through two separate channels: the direct effect through household responses, and an indirect effect through influences on effectiveness of collective action. The presence of the indirect effects prevents a precise confirmation of the household-level results from a cross-village regression. The cross-village regression is nevertheless interesting in its own right, as it indicates the importance of property rights and potential collective action determinants (contained in $\boldsymbol{\phi}_v$) in moderating collections. Contrasting the estimated coefficient of $\boldsymbol{\omega}_v$ in (25) with the household level estimates (of $\boldsymbol{\beta}$) allows assessment of separate direct and indirect effects in some cases.[14]

Equation (25) can be estimated from a cross-village regression. Alternatively, we can utilize household level information rather than village averages of collection levels. Note that the village effect in the household response equation (22) equals $K_v \equiv W_v + \beta_4 \frac{F_v}{n_v}$. Utilizing (24) and (25), this village effect can be expressed as

$$K_v = \psi_0 + \boldsymbol{\psi}_1.\boldsymbol{\omega}_v + \boldsymbol{\psi}_2.\boldsymbol{\phi}_v + \xi_v \tag{26}$$

where the residual ξ_v is uncorrelated with $\boldsymbol{\omega}_v$ and $\boldsymbol{\phi}_v$, on the basis of the assumption that the same is true of ε_v. An estimate of the village effect is then contained in the estimated residual for each household:

$$\hat{e}^4_{iv} \equiv F_{iv} - \hat{\boldsymbol{\beta}}.\omega_{iv} = \beta_0 + K_v + e^4_{iv} + e^5_{iv} \tag{27}$$

where $\hat{\boldsymbol{\beta}}$ denotes coefficients estimated from the household level regression, and $e^5_{iv} \equiv [\hat{\boldsymbol{\beta}} - \boldsymbol{\beta}].\omega_{iv}$ is the result of estimation error of household coefficients. Combining this with (26) we obtain

$$\hat{e}^4_{iv} = \beta_0 + \psi_0 + \boldsymbol{\psi}_1.\boldsymbol{\omega}_v + \boldsymbol{\psi}_2.\boldsymbol{\phi}_v + \xi_v + e^4_{iv} + e^5_{iv} \tag{28}$$

[14] An exact decomposition is not possible because the direct effect is $\boldsymbol{\beta}'$, which equals the product of $\frac{1}{1-\beta_4}$ and $\boldsymbol{\beta}$, and we do not have an independent estimate of β_4. But if some household characteristic was insignificant in the household regression, one can infer that the direct effect is insignificant. In that case the estimated coefficient of the mean of the corresponding characteristic in the village regression can be interpreted as the indirect effect.

a regression which can be run at the household level. This utilizes the fact that each household's collection within a village provides an independent estimate of the common village effect. This is exactly analogous to regression versions of the analysis of variance in controlled experiments, where $\boldsymbol{\omega}_v$ and $\boldsymbol{\phi}_v$ represent a common 'treatment' applied to a number of experimental units.

Estimation of (28) will however have to incorporate censoring of collections at the household level. In particular, the estimated residual in the presence of censoring is

$$\hat{e}^4_{iv} \equiv F_{iv} - \hat{\boldsymbol{\beta}}.\omega_{iv} = \max[-\hat{\boldsymbol{\beta}}.\omega_{iv}, \varphi_0 + \boldsymbol{\psi}_1.\boldsymbol{\omega}_v + \boldsymbol{\psi}_2.\boldsymbol{\phi}_v + \xi_v + e^4_{iv} + e^5_{iv}]. \qquad (29)$$

The parameters $\boldsymbol{\psi}_i$ in (29) can be estimated by maximum likelihood with random village effects ξ_v, using a random effects tobit estimator (Maddala (1987)) modified to accommodate a nonzero truncation point. This assumes Gaussian distributions for $\xi_v, e^4_{iv}, e^5_{iv}$, and independence from distributions of included variables $\boldsymbol{\omega}_v, \boldsymbol{\phi}_v$. The independence assumption is valid if all relevant village level determinants of utility, cost of firewood and collective action have been included. To control for potential endogeneity biases that may result from violations of this assumption, we instrument for village averages of consumption and collection times in estimation of (29), using village averages of their corresponding instruments used at the household level, besides geography and infrastructure variables that are unlikely to have a direct effect on firewood collections.[15]

Table 11 presents estimates from this regression. The measure of ethnic fragmentation is the probability that any two randomly chosen households in the sample belong to the same caste group (upper, middle or lower). Potential determinants of

[15] In particular, instruments with significant predictive power for mean consumption include mean value of inherited land, fraction of residents in middle and low castes, average hours of supply of electricity per week, distance to agricultural extension service centers, latitude and longitude. For mean collection time relevant instruments include electricity supply, mean literacy of parents of household heads, and mean age of household heads.

collective action within the village are average consumption, population size, inequality in consumption and in landownership, proximity of the forest (representing the stakes of the community in forest conservation), average gap below the poverty line of $1 a day per capita, ethnic fragmentation, standard deviation of collection times (representing preference heterogeneity and ease of mutual monitoring), and fraction of households belonging to forest user groups. Geographical determinants of need and collection cost include elevation, a dummy for occurrence of natural disaster in the previous five years, and proximity to roads and market centers. Apart from this we include averages of all variables entering the household regression, unless they have already been included within the list of collective action determinants.

The results of Table 11 are consistent with the previous household results, in conjunction with standard theories of collective action. Among the variables entering only via their impact on collective action, only ethnic fragmentation has a significant (positive) impact. This variable captures difficulties that ethnically divided communities encounter in evolving and implementing common codes of conduct. Moreover social sanctions may be limited to members of one's own caste, which implies weaker average levels of social sanctions in more heterogenous villages. The only other collective action variable of moderate significance is dispersion of collection times. Inequality, poverty and population size in particular do not have any significant effect. The effect of the forest user groups on collection activities appears to be insignificant, in contrast to the results of Edmonds (2002) for the Arun Valley area.

Regarding average consumption, the effect is positive and significant, reinforcing our earlier evidence against PEH at the household level. The higher significance of consumption at the village level could either reflect the multiplier effect resulting from social norms, or weaker collective action in more well-off villages. The coefficients of asset ownership patterns (interacted with collection time) have exactly the same patterns of signs as in the household regression, with the estimated coefficients between two to five times the estimated coefficients at the household level. The coefficients are however imprecisely estimated, with only the education variable statistically significant.

Finally, Table 12 combines the results of the inter-household and village effect regressions to simulate the effects of changes in some of the significant determinants of village-wide collection levels. Specifically, we simulate changes in collection activities at the household level from the combined model

$$F_{iv} = \max[0, (\beta_0 + \psi_0) + \boldsymbol{\beta}.\omega_{iv} + \boldsymbol{\psi}_1.\boldsymbol{\omega}_v + \boldsymbol{\psi}_2.\boldsymbol{\phi}_v + \xi_v + e^4_{iv}] \quad (30)$$

where $\boldsymbol{\beta}$ is estimated from the inter-household regression reported (for Version 1) in Table 5, and $\boldsymbol{\psi}_i, i = 1, 2$ from the village effect regression reported in Table 11. Effects of asset changes incorporate both the induced wealth effects (operating through their effect on consumption) and on the shadow cost of collection time (operating through interactions with collection time). These simulations also take into account the censoring effects, unlike the last columns of Tables 5 and 11, which simply simulate the effect on the latent collection levels rather than the actual ones. In other words, they predict switches between collecting and not collecting firewood, over and above changes in levels of collections for those that collect.

The results show that changes in consumption result in almost equiproportionate changes in collection levels per household, with negligible switching effects. Changes in village population resulting from changes in the number of households have negligible switching effects and on per household collections, implying almost equiproportionate changes in total collections at the village level. These results suggest that rising consumption standards and population levels witnessed in the *terai* region of Nepal can account for the massive deforestation witnessed there in the last few decades. The effects with respect to consumption changes are of course opposite to what the PEH would predict, via the effect of growth in reducing poverty. In contrast to falling dependence on firewood predicted by PEH, our results suggest a sharp increase instead — the result of the wealth effect at the household level, possibly compounded at the village level by weakening collective action to regulate firewood collection.

Table 12 however offers one sobering conclusion concerning the process of development on firewood dependence. If the growth process is accompanied by spread of education and diversification into nonfarm occupations, the effect of rising consumption standards could be substantially moderated. The effect of every household head acquiring primary education (i.e., education upto the 5th grade) would result in a massive reduction in dependence on firewood, which would more than outweigh the effect of upto 40% growth in consumption standards.

TABLE 11: Village Effect Determinants:

Random Effects Tobit

Variable	Estimate (bootstr. s.e.)	Elasticity at 30th percentile	Elasticity at Median	Elasticity at 75th percentile	Effect of one one S.D. increase (95% CI=+/-)
Mean Consumption (I)	175.91** (84.27)	5.05	1.27	0.80	2.51 (2.36)
Mean Collection Time (I)	-0.43 (0.34)	-3.13	-0.78	-0.50	-1.67 (1.53)
Gini Consumption	-3.77 (3.74)	-0.96	-0.22	-0.13	-0.34 (0.67)
Gini Landownership	0.23 (2.78)	0.13	0.03	0.02	0.03 (0.78)
Average Poverty Gap	5.48 (4.83)	0.21	0.10	0.11	0.63 (1.09)
Std. Dev. Collection Time	0.73 (0.56)	0.87	0.25	0.17	0.89 (1.35)
Ethnic Fragmentation	3.48** (1.75)	0.97	0.28	0.19	0.78 (0.77)
Fraction in Forest User Group	-0.22 (2.14)	0.00	0.00	0.00	-0.04 (0.80)
Population	-0.19 (1.39)	-0.16	-0.05	-0.04	-0.39 (1.95)
Population Square	0.075 (0.276)				
Mean Household Size	-1.36** (0.59)	-5.34	-1.16	-0.65	-0.99 (0.84)
Fraction Female Headed Households	-4.76 (4.023)	-0.37	-0.08	-0.10	-0.60 (0.99)
Mean Fraction Children	20.37 (30.47)	4.94	1.11	0.65	1.34 (3.94)
Mean Fraction Prime-Age Males	16.17 (29.59)	5.01	1.09	0.61	0.85 (3.06)
Mean Fraction Prime-Age Females	20.58 (28.40)	6.55	1.43	0.78	0.96 (2.61)
Mean Fraction Old Females	16.32 (51.18)	0.20	0.05	0.05	0.23 (1.40)
Mean of Land Owned* Collection Time	-0.71 (0.61)	-0.14	-0.05	-0.05	-1.48 (2.53)
Mean of Nonfarm Assets* Colection Time	-3.62 (10.94)	-0.00	-0.00	-0.00	-0.42 (2.48)
Mean of Cows Owned* Collection Time	0.04 (0.04)	0.00	0.00	0.00	0.00 (0.00)
Mean of Head Schooling* Collection Time	-0.17* (0.09)	-0.87	-0.29	-0.24	-1.23 (1.25)

TABLE 9 continued next page

TABLE 11 continued

Variable	Estimate (bootstr. s.e.)	Elasticity at 30th percentile	Elasticity at Median	Elasticity at 75th percentile	Effect of one one S.D. increase (1/2 95% CI width)
Time to Dirt Road	-0.14*	-0.04	-0.04	-0.09	-1.79
	(0.09)				(2.16)
Time to Market Center	0.13	0.18	0.05	0.05	0.84
	(0.12)				(1.45)
Time to Paved Road	0.08	0.14	0.05	0.10	1.22
	(0.07)				(1.92)
Elevation	2.49	0.00	0.00	0.00	0.00
	(1.55)				(0.00)
Elevation Squared	-0.38				
	(0.38)				
Natural Disaster Dummy	-1.27	0.00	-0.25	-0.13	-0.63
	(0.90)				(0.88)

No. of observations= 1350; 130 villages. 550 runs for bootstrapping

Wald chi-sq (30) = 154.70, p-value for chi-sq test for joint significance =0.00

446 left-censored observations, 904 uncensored observations

constant term and region dummies included in regression, not reported here

(I) denotes instrumented; **: significant at 5%; *: significant at 10%.

Simulations computed at median values for variables entering nonlinearly

TABLE 12: Simulated Change in Firewood Collection

Change	Change in Number of households not collecting	Change in per household collection for those collecting	Change in Total Predicted Collection (% change)
1. Increase consumption by 10% for all households	-18	0.63	982 (10.1)
2. Decrease consumption by 10% for all households	12	-0.55	-818 (-8.42)
3. Increase population by 10%	8	-0.03	927 (9.54)
4. Decrease population by 10%	-9	-0.02	-999 (-10.28)
5. Every head gets primary education (5 years schooling)	292	-1.69	-3883 (-39.99)
6. Increase nonfarm assets by 10% for all households	-1	0.07	95 (0.97)
7. Combine 5 with 20% increase in consumption and nonfarm assets	190	-0.70	-2185 (-22.50)
8. Combine 5 with 43.5% increase in consumption and nonfarm assets	111	0.65	-9 (-0.09)
No. observations = 1421, No. villages = 143			
Status quo: 88 households not collecting, mean positive collection =7.29, total predicted collection =9711			
Simulations with respect to given variable(s) all other variables at their observed values			

6 Concluding Comments

Our analysis suffers from a number of shortcomings, many of which stem from the nature of the data we used. The results are based on cross-sectional differences across households and village at a point of time, whose relevance to understanding shifts over time is difficult to assess. The use of panel data over time would be a big step forward. Other data limitations concern absence of information on forest stock and quality: do differences in firewood collection levels drive deforestation? Or are other factors, such as household demand for timber, changes in forest area resulting from conversion to agricultural land, private concessions to timber merchants, and illegal felling more important? To assess this question we would need data concerning changes in forest stock over time, for instance from land satellite images or forest surveys.

The Nepal LSMS data is poor with respect to information concerning prices and availability of fuel substitutes and complements to firewood: the responses contain many missing values which shrink the sample size considerably and were not included in the regressions to avoid possible sample selection biases. Understanding the process by which the extent of substitutability among alternative energy sources is expanded is of crucial policy importance. The process of modernization can conceivably be modified by policies of expanding transport networks, and increasing availability of fuel substitutes.

Little or no information was available concerning informal collective action governing use of forest products, forcing us to rely on imperfect proxies. Information concerning membership in forest user groups was also not available. This prevented analysis of the extent and effectiveness of local collective action in limiting firewood collections.

In our ongoing extension of this project to villages in the Indian Himalayas, we are attempting to gather better information on all these dimensions. Contrasting the experience of different Indian states, and of these with Nepal will also be interesting. It is important to reiterate that the patterns observed in Nepal may not be representative of resource problems in other developing countries; it is necessary to extend our analysis to the contexts of alternative resources and alternative countries before any general conclusions can be drawn.

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Appendix: Household Results with Estimated Shadow Cost of Time

Here we describe results at the household level utilizing a proxy for the household shadow cost of time. Since we are only interested in variations of the shadow cost across different households within the same village, these variations will be mirrored in corresponding variations in the average product of labor under the following assumption. Suppose that every productive activity within a given village is characterized by a Cobb-Douglas production function of the form $a_{iv}k_v s_{iv}^{\tau}$, where a_{iv} depends on assets owned by the household, k_v depends on relevant prices and productivity of the activity in the village, and τ is a common labor elasticity. The marginal product of labor of household i in productive activities then equals $\tau a_{iv}k_v s_{iv}^{\tau-1} \equiv \tau p_{iv}$, where p_{iv} denotes the average product of labor of the household. Intravillage variations in the shadow cost of labor then correspond to variations in the average product of labor across different households.

Under these assumption we can calculate the following proxy for the shadow cost for household i in village v:

$$\hat{c^l_{iv}} = \sum_{j=1}^{4} \sum_{m} I_{im} r_{imj} e_{ijv} \tag{31}$$

where $I_{im} = \frac{1}{p_{iv}}$ if household member m is one of p_{iv} members listed by the household as involved in collecting firewood, and 0 otherwise, r_{imj} is the fraction of m's time spent in occupation j and e_{ijv} is the income per hour of the household's labor in occupation j. Time allocated to leisure can be valued either according to market wage rates or zero, which represent upper and lower bounds to the value of leisure.

Table 13 shows the variation in the resulting estimates of the shadow cost of collection time across the 20 different consumption percentile groups. Irrespective of how leisure is valued, there is no discernible tendency for the shadow cost to rise with consumption; if anything it tends to decline somewhat. This table however does not control for village effects. It also shows an additional feature which tends to counteract the PEH: poorer households tend to take more time to collect firewood than the rest of the population.

TABLE 13: Variation in Collection Time and Estimated Shadow Cost of Collection Time Across Different Consumption Percentile Groups

Consumption Percentile Group	Mean Consumption (Rs.)	Mean Collection Time (hrs)	Estimated Shadow Cost Valuing Leisure at market wage	Estimated Shadow Cost Valuing Leisure =0
1	8246	5	1.82	0.59
2	11254	4	1.21	0.32
3	13554	4	1.61	0.52
4	15421	3	1.51	0.39
5	17865	3.5	1.52	0.45
6	19499	3.33	1.41	0.38
7	20887	3.25	1.22	0.37
8	22896	3.17	1.33	0.37
9	25033	3.75	1.34	0.49
10	27189	3.08	1.41	0.42
11	29008	3.00	1.69	0.47
12	31153	4	1.24	0.39
13	34169	3	1.05	0.39
14	37607	3	1.62	0.58
15	41255	3	0.90	0.34
16	45766	3	0.95	0.21
17	51297	3.25	1.47	0.32
18	60342	3	1.25	0.24
19	72719	3.08	1.64	0.49
20	101606	2.50	1.03	0.39

The estimate of the shadow cost of collection time permits estimation of equation (9), under the additional assumption that the shadow labor cost is an exogenous household characteristic, independent of time devoted to collecting firewood. The latter assumption would hold in a world where the marginal utility of leisure is constant over the relevant range for each household and thus equal to the shadow cost. Table 14 presents the results of the estimation of (9) using PANTOB. The coefficient of shadow cost (interacted with collection time) is positive and insignificant. Thus not only is there absence of evidence that the shadow cost of collection time is lower for poorer households, there is also no evidence that the shadow cost matters for collection activities.

TABLE 14: Household Panel Latent Firewood Collection Determinants: Using Shadow Cost of Collection Time

	Cost of Leisure= 0	**Cost of Leisure= expected wage**
Variable	Estimate (bootstr. std. err.)	Estimate (uncorrected std. error)
Consumption (I)	1.15 (62.12)	4.55 (61.87)
Consumption Square (I)	146.02 (647.02)	116.73 (645.54)
Shadow Cost* Collection Time(I)	0.05 (0.03)	0.01 (0.01)
Household Size	1.42** (0.38)	1.39** (0.37)
Household Size Square	-0.06** (0.03)	-0.05 (0.03)
Fraction Children	-4.93** (2.47)	-4.71* (2.46)
Fraction Prime-Age Males	-3.67* (2.11)	-3.54* (2.10)
Fraction Prime-Age Females	-2.29 (2.14)	-2.21 (2.13)
Fraction Old Men	-0.17 (2.68)	-0.17 (2.67)
Female Head	0.29 (0.36)	0.27 (0.36)
Time to Market	0.00 (0.01)	0.00 (0.01)
Time to Shop	-0.03 (0.02)	-0.03 (0.02)
No. of observations= 1255; p-value for chi-sq test for joint significance =0.00 (I) denotes instrumented; *: significant at 10%, **: significant at 5%		