

The Environmental Impact of Poverty: Evidence from Firewood Collection in Rural Nepal¹

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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 that poor households rely more on environmental common property resources than the non-poor. Household data from the World Bank 1995-95 Living Standards Measurement Survey for 215 Nepal villages reveals that poorer households collect substantially less firewood than others in the same village. No evidence for PEH can be found 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 sanctions or peer effects within villages. The results imply growth in living standards *per se* would raise collections significantly but this would be reversed if accompanied by spread of primary education.

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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 (1997, 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 has also been frequently discussed in this literature (owing to dependence of the poor on forest products), 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.

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, both in absolute terms and 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 a comparison of CPR use of the poor relative to the non-poor, or how it changes with the degree of poverty. 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, where intravillage variations in firewood collection are related to differences in consumption levels of households, allowing for presence of village fixed effects that reflect unobservable influences at the village level. 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.⁷ 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 a two-step Heckman-type correction for potential biases from unobservability of collection times for noncollectors, and potential endogeneity of consumption levels and collection times.

We find no evidence in favor of the PEH. The raw data show that poor households collect significantly less than non-poor households within the same village. We decompose this into effects of varying consumption levels (the pure ‘wealth’ effect) and of varying shadow cost of labor 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 collections to be increasing and concave with respect to consumption (though these effects are statistically insignificant). The absence of a negative wealth effect is consistent with primary reliance on firewood as a source of household fuel for the vast majority of households in the sample, a phenomenon which presumably reflects absence of affordable fuel substitutes in these villages. The interaction between consumption and collection time also turns out to be positive (and insignificant), in contrast to the prediction of the PEH

⁷Deforestation 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)).

that it is significantly negative owing to the effect of rising living standards on the shadow cost of collection time of households. A proxy for the shadow cost of collection time turns out to vary little across households in different consumption classes. This reflects a pattern of increasing specialization within wealthier households between income earning activities and firewood collection activities. Significant determinants of firewood collection at the household level include household size (larger households collecting less per capita), occupational structure (shift into farm or nonfarm occupations and out of livestock rearing is associated with lower collections), and levels of education of heads of household (more educated households collect less).

Residuals from the household regression provide an estimate of the village effects, which are subsequently regressed against village characteristics (using a random effects tobit estimator to correct for censoring effects).⁸ Under the hypothesis of interdependence of collection activities of different households within a village owing 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 turn out to increase significantly with respect to average consumption standards, proximity to the forest and to (dirt) roads, smaller household size and educational standards. In addition we also find a significant positive effect of higher caste fragmentation within the village, presumably reflecting the adverse impact on informal collective action regulating

⁸In 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.

firewood collection by residents. Interestingly, the effect of creation of forest user groups in Nepal's community forestry schemes has no significant impact on collection levels.

These results suggest that appropriate policy responses to limiting firewood collection in Nepal are quite distinct from what the PEH would suggest. Under the PEH, policies which raise incomes of the poor would reduce levels of collection, whereas our results indicate that the consequent rise in consumption standards would significantly raise collections. Simulations with respect to significant determinants of collection levels implied by the estimated coefficients of our model reveal that rising consumption levels *per se* across all households within a village would result in approximately equiproportionate increase in collection activities. But if the rise in consumption standards were accompanied by universal primary education, collections would fall substantially. Environmental sustainability thus necessitates closer attention to qualitative characteristics of the process of development, i.e., to shifts in occupation and educational patterns, and in availability of modern fuel substitutes (which presumably underlies absence of negative wealth effects).

Our results stand in contrast to those of Chaudhuri and Pfaff (2002) and Foster and Rosenzweig (2002) concerning the effects of household income on firewood use or collections in Pakistan and India respectively. Chaudhuri and Pfaff find an inverse U-shaped relation 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 nature of access to alternative fuels, education levels and different levels of per capita income. For instance, the switch to modern fuels in Pakistan identified by Chaudhuri and Pfaff occurs in particular among urban households, whilst even within rural households there was significant use of kerosene and electricity in cooking.⁹ Educational levels in rural Pakistan appear to be substantially above those in Nepal.¹⁰ Moreover, our results indicate that firewood collections have a rising, concave relationship with household consumption,

⁹The proportion of rural households using kerosene and electricity for cooking in Pakistan was 90% and 58% respectively, in contrast to 3% and 1.4% in Nepal.

¹⁰Average 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.

a relationship which will eventually become downward sloping for ranges of consumption beyond those observed in the Nepal sample. Hence the differences between the results for the three countries may also arise from differences in levels of living standards.

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

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

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} , and household family size and composition hs_{iv} , the household has the following indirect utility function

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

where $w(\cdot)$ is obtained by maximizing $u(\cdot)$ subject to $p_v \cdot q_{iv} \leq E_{iv}$. 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 depends on (i) the time it takes to collect, (ii) the opportunity cost of this time to the household, and (iii) any fees that the household may have to pay to a forest guard.

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:

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

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. Besides this, 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 simply denote this by hs_{iv} . The labor allocated to occupation j is denoted s_{iv}^j , so the time allocation constraint is

$$hs_{iv} = \sum_{j=1}^5 s_{iv}^j + l_{iv} + t_{iv} \quad (4)$$

The budget constraint is given by

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

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 variable captures 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 $\frac{F_v}{n_v}, W_v \equiv$

$(p_v, w_v^2, w_v^3, a_v, c_v^f)$. The household's problem is to select firewood collection F_{iv} and labor allocation $l_{iv}, s_{iv}^j, j = 1, \dots, 5$ to maximize its 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 the household first decides how to allocate its remaining time $L_{iv} \equiv hs_{iv} - T_{iv}F_{iv}$ between 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.

Suppose the household collects a positive amount of firewood. Then its best response to the collection activities of others in the village can be found by equating 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

$$MC_{iv} = c_{iv}^l T_{iv} + c_v^f \quad (6)$$

where

$$c_{iv}^l \equiv \left[\frac{\frac{\partial w}{\partial l_{iv}}}{\frac{\partial w}{\partial E_{iv}}} \right] \frac{\partial l_{iv}}{\partial L_{iv}} + \sum_{j=1}^5 \frac{\partial y^j}{\partial s_{iv}^j} \frac{\partial s_{iv}^j}{\partial L_{iv}} \quad (7)$$

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

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

upon taking a linear approximation with zero-mean error η_{iv} , and where α'_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 the sign of α_1, α_6 to be negative, and of α_3 to be positive (where hs_{iv} is interpreted as a measure of household size). 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_{iv}^l 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 the expressions (6) and (8) for marginal cost and marginal utility respectively:

$$\begin{aligned} F_{iv} &= \frac{1}{-\alpha_1 - \alpha_4} [\alpha_0 + \alpha_{21}E_{iv} + \alpha_{22}E_{iv}^2 + \alpha_3hs_{iv} - \alpha_4\frac{F_v}{n_v} + \alpha'_v - c_v^f + c_{iv}^lT_{iv} + \eta_{iv}] \\ &= \gamma_1 + \gamma_{21}E_{iv} + \gamma_{22}E_{iv}^2 + \gamma_3hs_{iv} + \gamma_4\frac{F_v}{n_v} + \gamma_5c_{iv}^lT_{iv} + \alpha_v + e_{iv}^1 \end{aligned} \quad (9)$$

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. The effect of higher collection cost is represented by γ_5 . 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) which can be estimated from the data with village fixed effects can therefore be used to test PEH.

The problem with this 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 substantial unemployment and surplus labor in these villages, and because the majority of households are exclusively self-employed. Moreover, the above derivation of the best response equation makes the assumption that the shadow cost of time is independent of the amount of time devoted to collection. As we will see the collection times involved are quite considerable on average, so this assumption is questionable. We shall however later present estimated versions of this equation using certain proxies for the shadow cost which will be valid under some strong assumptions concerning the nature of the household production functions.

It is better to avoid these problems by using an alternative approach, which treats the shadow cost as endogenous, and relates it to household and village characteristics. By definition:

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

If we continue to assume separability of utility between leisure and and other arguments

entering the utility function, the above derivative depends simply on leisure: $L_{iv} - \sum_j s_{iv}^j$. Taking a linear approximation, we obtain

$$c_{iv}^l = \kappa_1 + \kappa_2[hs_{iv} - F_{iv}T_{iv} - \sum_j s_{iv}^j] + e'_{iv} \quad (11)$$

where e'_{iv} denotes a zero mean approximation error, and $\kappa_1 > 0, \kappa_2 < 0$. The right-hand-side of (11) includes s_{iv}^j , time allocated to 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, nonfarm assets or livestock would end up devoting more time to those activities (under the plausible assumption of complementarity between asset ownership and returns from the corresponding occupation). We can therefore express the shadow cost as a function of time collecting firewood and household characteristics:

$$c_{iv}^l = \delta_1 + \delta_2 E_{iv} + \delta_3 hs_{iv} + \delta_4 F_{iv}T_{iv} + \delta_5 \theta_{iv} + V_v + e''_{iv} \quad (12)$$

This equation includes the household's consumption among its characteristics that affect the shadow cost of time (after controlling for asset ownership vector θ_{iv}), and takes it to be fixed in the spirit of Engel curve estimation in household demand analysis. This allows higher levels of consumption to directly lead to a higher shadow cost of time (through effects on valuation of leisure, or on returns to occupations whose asset values are unobserved), as is typically assumed in arguments for the PEH.¹¹ In an economy with so much self-employment, however, it is not reasonable to treat household income or consumption as fixed. Consumption is jointly determined with time allocated to production, so we should either drop the consumption term in (12), or estimate its coefficient using suitable instruments for consumption. Both these approaches will be used in our estimation. In the version where the term in consumption is retained, the effects of asset ownership can be interpreted as representing the effect of altering occupational structure on the shadow cost

¹¹For instance, if there are wealth differences between households arising from inheritances or remittances, there will be consequent wealth effects on the demand for leisure: wealthier households will devote less effort to income earning activities. On the other hand, higher consumption could also result from higher values of productive assets owned which are unobserved in the data: then we would get the opposite effect with such households devoting more time to productive occupations.

of labor: with the level of consumption of the household fixed, changes in asset ownership will principally impact the shadow cost by altering the allocation of household labor across different occupations.

In this approach, the marginal cost of collection for the household reduces to

$$\begin{aligned}
MC_{iv} &= c_v^f + T_{iv}[\delta_1 + \delta_2 E_{iv} + \delta_3 h s_{iv} + \delta_4 F_{iv} T_{iv} + \delta_5 \theta_{iv} + V_v + e_{iv}''] \\
&= c_v^f + \delta_1 T_{iv} + \delta_4 T_{iv}^2 F_{iv} + \delta_2 E_{iv} T_{iv} + \delta_3 h s_{iv} T_{iv} + \delta_5 \theta_{iv} T_{iv} + \delta_6 V_v T_{iv} + e_{iv}^3.
\end{aligned} \tag{13}$$

Equating with marginal utility, we obtain the best response equation

$$\begin{aligned}
F_{iv} &= \frac{1}{-\alpha_1 - \alpha_4 + \delta_4 T_{iv}^2} [\alpha_0 + \alpha_{21} E_{iv} + \alpha_{22} E_{iv}^2 + \alpha_3 h s_{iv} + \alpha_4 \frac{F_v}{n_v} + \alpha'_v - c_v^f - \delta_0 T_{iv} \\
&\quad - \delta_2 E_{iv} T_{iv} - \delta_3 h s_{iv} T_{iv} - \delta_5 \theta_{iv} T_{iv} - \delta_6 V_v T_{iv} - e_{iv}^3]
\end{aligned} \tag{14}$$

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

$$\begin{aligned}
F_{iv} &= \beta_0 + \beta_{21} E_{iv} + \beta_{22} E_{iv}^2 + \beta_3 h s_{iv} + \beta_5 T_{iv} + \beta_6 T_{iv}^2 + \beta_7 E_{iv} T_{iv} + \beta_8 \theta_{iv} T_{iv} \\
&\quad + (\beta_4 \frac{F_v}{n_v} + W_v) + e_{iv}^4
\end{aligned} \tag{15}$$

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.¹²

If we now drop the assumption of a positive interior level of collection, we can replace (15) by its censored version:

$$F_{iv} = \max[0, \beta_0 + \beta_{21} E_{iv} + \beta_{22} E_{iv}^2 + \beta_3 h s_{iv} + \beta_5 T_{iv} + \beta_6 T_{iv}^2 + \beta_7 E_{iv} T_{iv} + \beta_8 \theta_{iv} T_{iv} + Y_v + e_{iv}^4] \tag{16}$$

where $Y_v \equiv \beta_4 \frac{F_v}{n_v} + W_v$.¹³ In (16) the interaction term $E_{iv} T_{iv}$ arises only if consumption is a determinant of shadow cost of time over and above the effect of assets owned, and

¹²In 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.

¹³Here we exploit the fact that indirect utility of the household is concave with respect to firewood, while the marginal cost is increasing.

drops out if this is not the case. This suggests that we estimate this best response equation both with and without this interaction term. The PEH now corresponds to the hypothesis that the wealth effects are negative ($\beta_{21}, \beta_{22} < 0$), and that the interaction effect between consumption and firewood collection time has a negative coefficient ($\beta_7 < 0$).

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 2713 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. 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 3000 feet, with a standard deviation of 3000 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 1.5 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 income 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. 45% belonged to upper castes (*brahmin* or *chhetry*), 28% to middle castes (*magar, thuru, newar, tamang, rai, gurung, limbu*), 27% to Muslims and lower castes (*kami, damai and surki*). Hence there was greater ethnic than religious fragmentation. 19% 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 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.¹⁴ 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, 11% of households in the sample reported collecting from a community forest. At the same time the average fraction of such households within a village was 5%, and 43% of the villages had at least one such household in the sample.

¹⁴Over 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.

TABLE 1: Household Characteristics: Descriptive Statistics

Variable	Number of Observations	Number of Zeroes	Mean	Standard Deviation	Minimum	Maximum
Firewood Collected (bharis/month)	2671	807	5.79	5.77	0	35
Collection Time (hrs per bhari)	2335	0	5.08	2.89	0.17	25.02
Annual Consumption Expenditure (Rs.)	2713	0	35312	27625	2869	445935
Fraction Labor Non-Agriculture (self-employed)	2674	2072	0.08	0.21	0	1
Fraction Wage Labor Agriculture	2674	1590	0.16	0.25	0	1
Fraction Wage Labor Non-Agriculture	2674	1705	0.11	0.20	0	1
Number of Cows Owned	2440	241	3.72	3.12	0	27
Household Size (Adult Equiv.)	2713	25	4.41	2.06	0.00	27
Belongs to Forest User Group	2712	2424	0.11	0.18	0	1
Years Schooling Household Head	2713	1913	1.87	3.38	0	17
Female-Headed Household	2713	2362	0.13	0.34	0	1
Upper Caste (Brahmin-Chetry)	2711	1757	0.35	.48	0	1
Middle Caste (Magar-Lumbu)	2711	1963	0.28	0.45	0	1
Low Caste & Muslim	2711	1992	0.27	0.44	0	1
Hindu	2711	357	0.87	0.34	0	1
Buddhist	2711	2536	0.06	0.25	0	1
Muslim	2711	2615	0.04	0.18	0	1
Other Non-Hindu Religion	2711	2681	0.01	0.10	0	1

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	.05	.22	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)	185	0	5.09	2.41	0.50	12.40
Standard Deviation Collection Time	185	9	1.50	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

4 Household-Level Intra-Village Estimation

4.1 Estimation Procedure

The best response equation (16) 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. 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 (which is 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 have to predict collection times based on observed household characteristics. Accordingly we postulate

$$T_{iv} = \lambda_1 \theta_{iv} + \lambda_2 Z_{iv} + \lambda_v + \eta_{iv}^1 \quad (17)$$

where θ_{iv} represents vector of household assets owned, and Z_{iv} is a vector of instruments uncorrelated with the error term in the firewood equation (16). 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, or the fact that recent migrants generally locate on the outer fringes of the village (given the general absence of a housing market within these villages, which implies that existing households rarely move following an influx of migrants). The fixed effect in (17) 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 (17), we have to encounter the endogenous sample selection problem again: 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

$$\begin{aligned}
F_{iv}^* &\equiv \beta_0 + \beta_{21}E_{iv} + \beta_{22}E_{iv}^2 + \beta_3hs_{iv} + \beta_5T_{iv} \\
&\quad + \beta_6T_{iv}^2 + \beta_7E_{iv}T_{iv} + \beta_8\theta_{iv}T_{iv} + \left(\beta_4\frac{F_v}{n_v} + W_v\right) + e_{iv}^4 \\
&> 0.
\end{aligned} \tag{18}$$

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 (17) and (18). At the second stage a weighted least squares panel regression of (17) 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 with at least one collector:

$$\hat{\lambda}_v = \frac{\sum_{i \in C_v} (T_{iv} - \hat{\lambda}_1\theta_{iv} - \hat{\lambda}_2Z_{iv})}{NC_v} \tag{19}$$

where C_v denotes the set of collecting households in village v , and NC_v the number of such households. We can then predict the collection times for noncollectors using the estimated coefficients of (17) and their observed characteristics θ_{iv}, Z_{iv} . These households can be included in estimation of (16) 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:

$$E_{iv} = \nu_1 + \nu_2\theta_{iv} + \nu_3hs_{iv} + \nu_4I_{iv} + \nu_v + \eta_{iv}^2. \tag{20}$$

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 (16) after controlling for the households consumption and other characteristics that enter it.¹⁵ 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 (17)) so this necessitates re-estimating the coefficients of (17). Following this, we obtain the coefficients of the collection equation (16) upon applying PANTOB to the data using the predicted collection times for noncollectors (using the estimated coefficients of (17), and consumptions predicted by the estimated coefficients of (20)). The PANTOB standard errors then 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 (17) and (20).¹⁶

Before presenting the estimation results, we show a plot and 95% confidence intervals of deviations of firewood collection from village means for twenty different percentile groups (each corresponding to a five percentile group) in Figure 1. Figure 2 plots these deviations against mean consumption levels of these different groups. These plots show 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). Figure 2, the most relevant for our purposes, displays a rising concave pattern with respect to consumption levels, which flattens out for the top half of the sample. It also suggests that a quadratic term should suffice to pick up the nonlinearity of the wealth effect.

¹⁵Estimation of (20) 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.

¹⁶In 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 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. 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).

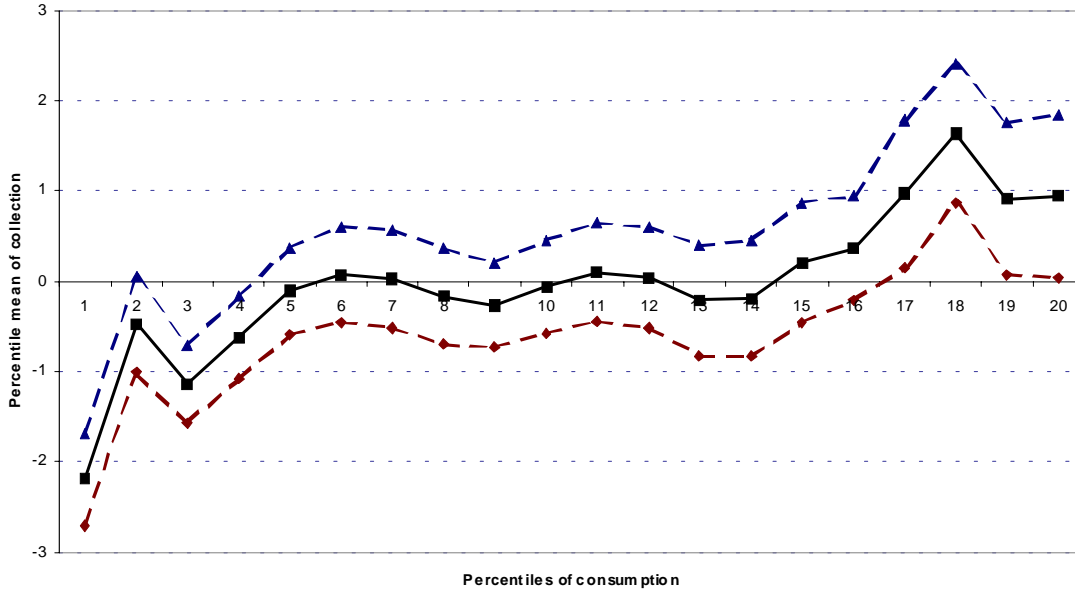


Figure 1: DEVIATIONS OF FIREWOOD COLLECTION FROM VILLAGE MEAN FOR DIFFERENT CONSUMPTION PERCENTILE GROUPS

Table 4 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 5. Firewood collection is increasing and concave in consumption when it is treated as endogenous, though these coefficients are not statistically significant. The interaction between consumption and collection time has a positive insignificant coefficient, also in contrast to the prediction of PEH.

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 land, nonfarm assets owned, and education of head of household. This suggests the role of occupational choice in moderating collection levels. Household age and gender

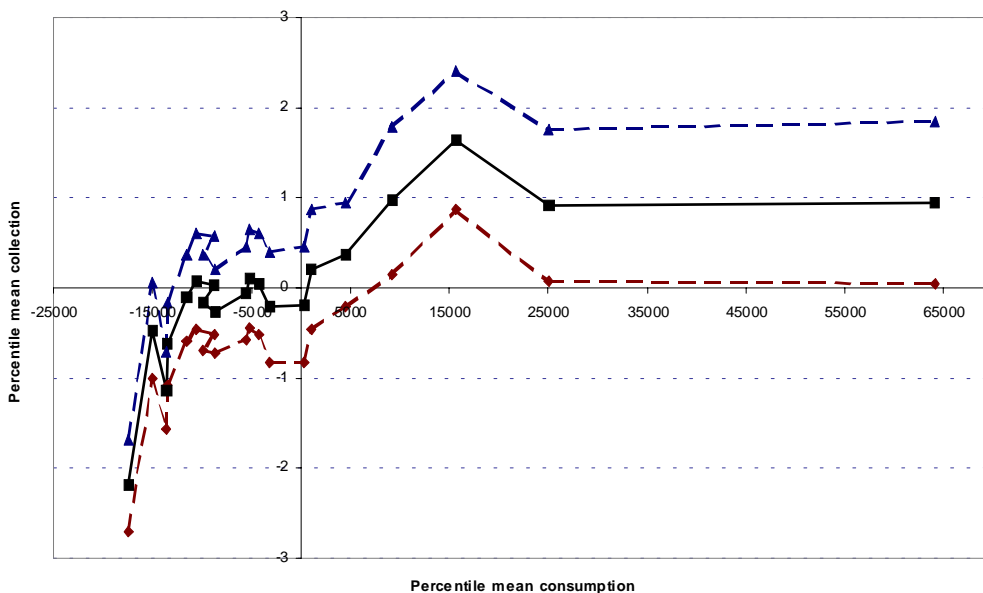


Figure 2: DEVIATIONS OF FIREWOOD COLLECTION FROM VILLAGE MEAN FOR DIFFERENT LEVELS OF CONSUMPTION

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.

Since the coefficients of consumption in these regression represent the wealth effect, one reason for the failure of PEH is that this wealth effect is positive throughout the range of consumption observed in the sample. Rising consumption causes the demand for energy in the home to rise. In the absence of reasonably priced and widely accessible fuel substitutes, it is natural that households resort to increasing collection of firewood. The estimated relationship with consumption nevertheless is inverse U-shaped, suggesting that the wealth effect will eventually turn negative at higher levels of consumption beyond those observed in the sample. In that sense our results are not inconsistent with those for Pakistan and India obtained by Chaudhuri and Pfaff (2002) and Foster and Rosenzweig (2002) respectively: they may reflect the fact that these Nepalese villages are substantially poorer, have less

access to alternative fuel sources, and are less educated.

The other source of evidence against the PEH concerns its predictions concerning the shadow cost of collection time. Wealthier households are likely to be those with higher land, nonfarm assets, education and consumption standards: accordingly the interaction of these variables with collection time ought to have a significantly negative coefficient. Table 4 shows no evidence in favor of this prediction. In Table 5 the interaction with consumption is dropped, and then the coefficients of interaction with nonfarm assets and education are negative and significant. But since the regression does control for levels of consumption, these coefficients are more properly interpreted as effects of occupational structure rather than of poverty *per se*. The effect of poverty on shadow labor cost is best represented by the coefficient of the interaction of consumption and collection time, which we saw in Table 4 was positive and insignificant. Hence there seems no evidence of a significant positive effect of consumption standards on the shadow cost of collection time (which would have translated into a negative significant interaction effect on collections under the PEH).

**TABLE 4: 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				
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 5: 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 median values.

Why might the shadow cost of collection time 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 grandparents live within the same family and can be called upon to help out with firewood collection and other household tasks.

The Nepal LSMS contains information about the principal collectors of firewood within the household. Table 6 presents the breakdown of principal collectors between the household head, spouse, children, grandchildren and others (which may include domestic servants) for different consumption quartiles. There is a clear tendency for families to resort increasingly to children, grandchildren and others to collecting firewood in the wealthier households, and less on the household head. This pattern of increasing intrahousehold specialization between productive and home tasks may explain why the shadow cost of collection time does not rise with consumption standards.

TABLE 6: Identity of Principal Collectors within Households

Percent households in consumption quartile where following is a principal collector	Bottom Quartile	Second Quartile	Third Quartile	Top Quartile
Household head	72.2	59.9	57.7	46.0
Spouse	61.9	68.0	76.5	66.5
Children	24.3	33.5	39.8	54.0
Grandchildren	12.1	26.8	27.9	38.8
Others	10.5	26.8	37.5	48.7

It would be useful to confirm these interpretations with direct estimates of the shadow cost of collection time for every household. Since we are only interested in variations of

the shadow cost across different households within the same village (rather than levels), we can estimate the shadow cost under some additional assumptions in the following manner. 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 correspond to variations in the average product of labor across different households.

This suggests we measure the average product of labor in those sectors of productive activity to which the principal collectors of firewood devote their time, and examine variations across households of different wealth. We therefore calculate the following proxy for the shadow cost for household i in village v :

$$\hat{c}_{iv}^l = \sum_{j=1}^4 \sum_m I_{im} r_{imj} e_{ijv} \quad (21)$$

where $I_{im} = \frac{1}{p_{iv}}$ if household member m is one of p_{iv} members listed by the household as principally 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.

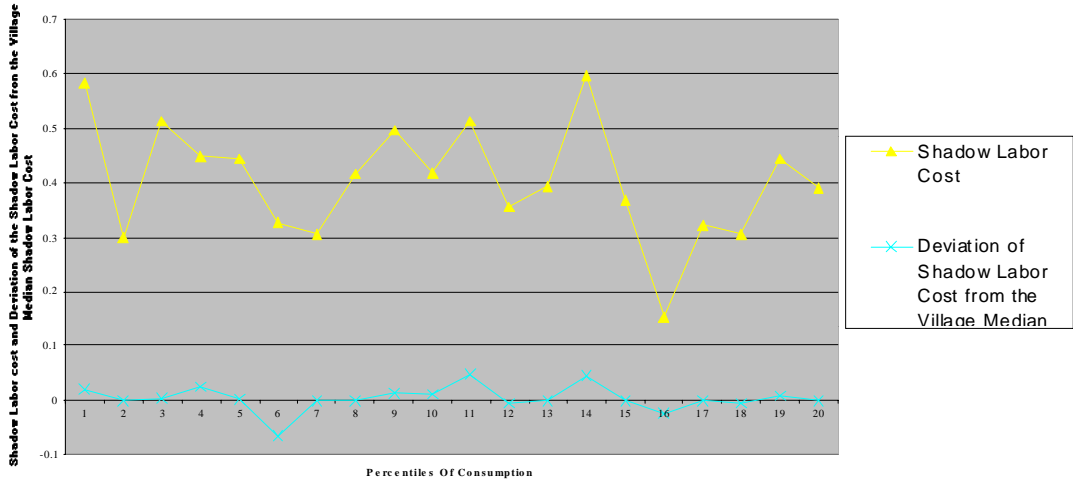


Figure 3: SHADOW COST OF COLLECTION TIME: DEVIATIONS FROM VILLAGE MEAN FOR DIFFERENT CONSUMPTION PERCENTILE GROUPS

Table 7 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. Figure 3 plots deviations of shadow cost for each group from the corresponding village median. Table 7 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 7: 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 8 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. Figure 4 plots the implied estimate of the wealth effect and shadow cost of collection effect against consumption. It reveals that the wealth effect overwhelmingly dominates the collection cost effect.

**TABLE 8: 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%		

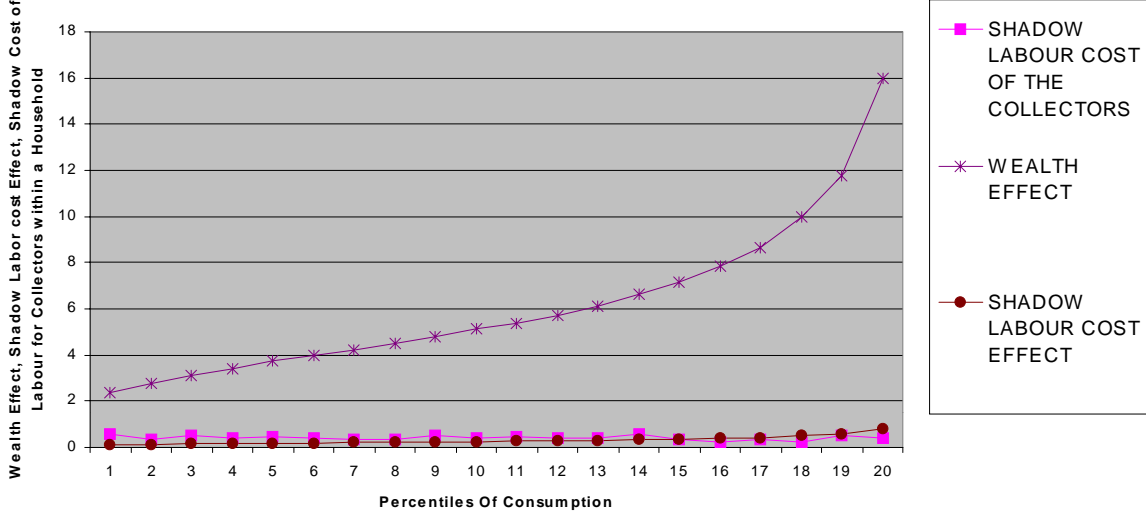


Figure 4: WEALTH EFFECT, SHADOW COST OF COLLECTION TIME EFFECT ON LATENT FIREWOOD COLLECTION FOR DIFFERENT CONSUMPTION PERCENTILE GROUPS

5 Village Effect Determinants

Equation (15) 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 β the corresponding coefficient vector, we can represent this response equation more compactly as follows:

$$F_{iv} = [\beta_0 + \beta \cdot \omega_{iv} + W_v] + \beta_4 \frac{F_v}{n_v} + e_{iv}^4. \quad (22)$$

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 ω_v of the relevant household characteristics:

$$\frac{F_v}{n_v} = \frac{1}{1 - \beta_4} [\beta_0 + \beta \cdot \omega_v + W_v]. \quad (23)$$

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 ω_v . Recall that the collection charge c_v^f 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 ω_v such as average levels and inequality in consumption, and a variety of village level variables (represented by the vector ϕ_v) that potentially affect collective action and geography.

$$W_v = \sigma_0 + \sigma_1 \cdot \omega_v + \sigma_2 \cdot \phi_v + \varepsilon_v \quad (24)$$

The vector ϕ_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:

$$\frac{F_v}{n_v} = \beta'_0 + [\sigma_1 + \beta'] \cdot \omega_v + \sigma'_2 \cdot \phi_v + \varepsilon'_v \quad (25)$$

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 ω_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 ϕ_v) in moderating collections. Contrasting the estimated coefficient of ω_v in (25) with the household level estimates (of β) allows assessment of separate direct and indirect effects in some cases.¹⁷

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

$$K_v = \psi_0 + \psi_1 \cdot \omega_v + \psi_2 \cdot \phi_v + \xi_v \quad (26)$$

where the residual ξ_v is uncorrelated with ω_v and ϕ_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

¹⁷An exact decomposition is not possible because the direct effect is β' , which equals the product of $\frac{1}{1-\beta_4}$ and β , 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.

residual for each household:

$$\hat{e}_{iv}^4 \equiv F_{iv} - \hat{\beta} \cdot \omega_{iv} = \beta_0 + K_v + e_{iv}^4 + e_{iv}^5 \quad (27)$$

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

$$\hat{e}_{iv}^4 = \beta_0 + \psi_0 + \psi_1 \cdot \omega_v + \psi_2 \cdot \phi_v + \xi_v + e_{iv}^4 + e_{iv}^5 \quad (28)$$

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 ω_v and ϕ_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

$$\hat{e}_{iv}^4 \equiv F_{iv} - \hat{\beta} \cdot \omega_{iv} = \max[-\hat{\beta} \cdot \omega_{iv}, \varphi_0 + \psi_1 \cdot \omega_v + \psi_2 \cdot \phi_v + \xi_v + e_{iv}^4 + e_{iv}^5]. \quad (29)$$

The parameters ψ_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 ξ_v , e_{iv}^4 , e_{iv}^5 , and independence from distributions of included variables ω_v , ϕ_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.¹⁸

¹⁸In 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.

Table 9 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 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 9 are broadly consistent with the previous household results, and with 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 heterogeneous 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

**TABLE 9: 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* Collection 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

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* (0.09)	-0.04	-0.04	-0.09	-1.79 (2.16)
Time to Market Center	0.13 (0.12)	0.18	0.05	0.05	0.84 (1.45)
Time to Paved Road	0.08 (0.07)	0.14	0.05	0.10	1.22 (1.92)
Elevation	2.49 (1.55)	0.00	0.00	0.00	0.00 (0.00)
Elevation Squared	-0.38 (0.38)				
Natural Disaster Dummy	-1.27 (0.90)	0.00	-0.25	-0.13	-0.63 (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

only the education variable statistically significant.

Finally, Table 10 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

$$F_{iv} = \max[0, (\beta_0 + \psi_0) + \beta \cdot \omega_{iv} + \psi_1 \cdot \omega_v + \psi_2 \cdot \phi_v + \xi_v + e_{iv}^4] \quad (30)$$

where β is estimated from the inter-household regression reported (for Version 1) in Table 4, and $\psi_i, i = 1, 2$ from the village effect regression reported in Table 9. These simulations also take into account the censoring effects, unlike the last columns of Tables 4 and 9, 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 10 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 reversed. 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 10 or even 20% growth in consumption standards.

TABLE 10: 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)	337	-2.31	-4753 (-48.94)
6. Increase nonfarm assets by 10% for all households	0	-0.01	-8 (-0.00)
7. Combine 1,5,6	282	-1.53	-3667 (-37.76)
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 also 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. This prevented analysis of the extent and effectiveness of such collective action in limiting firewood collections. It would also help to know of methods of effective enforcement of use regulations by either formal or informal means.

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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