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The Environmental Impact of Poverty: Evidence from Firewood Collection in Rural Nepal[1]

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Abstract

We investigate how firewood collection varied across households with differing living standards and assets in rural Nepal, using the 1995-95 and 2002-03 Living Standards Measurement Surveys. We control for village fixed effects, endogenous censoring, measurement error in living standards and heterogeneus effects of different assets. Collections are less sensitive to increases in education and non-farm assets compared with assets associated with traditional occupations such as livestock. There is no evidence in favor of the poverty-environment hypothesis, irrespective of which assets are associated with variations in living standards. Inverted-U effects (*a la* the environmental Kuznets curve) arise only with respect to education and non-farm business assets, in the 1995-96 sample.

1 Introduction

Forest degradation in the Himalayan region has assumed alarming proportions in recent decades. Between 1947 and 1980, Nepal's forest cover declined at an annual rate of 2.7% (from 57% to 23% of the national territory), and subsequently at an annual rate of 1.8% between 1980-2000 (Myers (1986), UNEP (2001), FRA (2000)). In the Indian mid-Himalayan region, the time needed by neighboring households to collect firewood increased 60% over the past quarter century, while collections per household decreased by 40% (Baland et al (2008)). The current evolution is partly irreversible, as fertile topsoil is being washed out by soil erosion in deforested areas. Deforestation and forest degradation have immediate consequences for the local population in terms of increased fuel scarcity, reduced supply of fodder and leaf-litter manure. Increased scarcity affect agricultural operations by reducing the time available for other farm activities. For instance, Cooke (1998) estimated that households in Nepal in 1982-83 spent eight hours per day on average collecting fuelwood, leaf fodder, grass and water. Children are significantly involved in collecting firewood, so forest degradation may induce lower levels of schooling and child health (Kumar and Hotchkiss (1988), Dasgupta (1995)). Reduced production of heat in the household may increase incidence of diseases for all members of the family (Amacher *et al* (2001)).

Degradation of Himalayan forests has wider consequences as well. The Himalayan range is amongst the most unstable of the world's mountains and therefore inherently susceptible to natural calamities (Ives and Messerly (1989)). There is evidence that deforestation aggravates the ravaging effects of regular earthquakes, and induce more landslides and floods. This affects the Ganges and Brahmaputra river basins, and contributes to siltation and floods as far away as Bangladesh (see Dunkerley *et al* (1981) and Metz (1991)). On a global scale deforestation hastens the depletion of ozone layer, inducing greater climate change. For all these reasons understanding the underlying causes of forest degradation is important.

A leading hypothesis about the economic determinants of environmental degradation is that underlying poverty of neighboring residents is the root cause. It is argued that poor households have no option but to rely on forests for their fuel and fodder needs. Initially proposed by the 1987 Brundtland Commission and the Asian Development Bank (Jalal (1993)), this 'poverty-environment hypothesis' (PEH) has subsequently received substantial attention from academics and policy experts.[7] A related view is expressed by the 'energy ladder' model, which predicts that higher incomes induce households to switch away from traditional fuels, such as cowdung and firewood, to higher quality but more expensive substitutes such as kerosene and gas (Arnold *et al* (2003)). According to these hypotheses, halting environmental degradation requires as a prior step the reduction of poverty.

A contrasting view is expressed by a different literature on 'environmental Kuznets curves' (EKC), which postulates an inverted 'U' between per capita income and pressures on the environment (e.g., Barbier (1997b), Grossman and Krueger (1995) or Yandle, Vijayaraghavan and Bhattarai (2002)). This hypothesis postulates that the effects of economic development and poverty reduction are non-monotonic: rising living standards initially increase environmental pressures, and later improve them. In

[7] See, e.g., Barbier (1997a, 1998, 1999), Duraiappah (1998), Jalal (1993), Lele (1991), Lopez (1998), Maler (1998), Baland and Platteau (1996), Angelsen and Wunder (2003).

poor countries located to the left of the turning point of the inverted-U, they predict that reducing poverty will further worsen environmental problems, in contrast to the PEH and the energy-ladder theories.

Different views in the literature concerning the economic determinants of environmental degradation can be interpreted as arising from differing presumptions concerning the direction and magnitude of associated wealth and substitution effects. Those arguing that growth and poverty reduction can improve the environment (following the PEH literature) stress the importance of the negative substitution effects, apart from the possibility that wealth effects may be negative. In the context of firewood, the substitution effect operates via the effect of increasing wealth on the shadow cost of time spent by household members collecting firewood. Moreover, firewood may be an inferior good: rising wealth raises households' ability to afford modern fuels purchased from the market, as well as their awareness and concern for the adverse health consequences of indoor air pollution of firewood usage. In contrast, the EKC hypothesis argues that reducing poverty may initially harm the environment, on the premise that wealth effects are positive (owing to rising energy demands with living standards) and strong enough for poor households to outweigh related substitution effects.

Given that the net effect is theoretically ambiguous, careful empirical analysis is needed to estimate the effect of rising living standards of households on firewood collection, and decompose this into associated wealth and substitution effects.[8] That

[8]Throughout this paper we use the term 'substitution' effect to denote the effect of wealth on shadow cost of collection, rather than the textbook interpretation as changes in utility-compensated demands.

is the purpose of this paper, using household level data for rural Nepal from the 1995-96 World Bank Living Standards Measurement Survey (LSMS). Robustness of these results is checked for the subsequent (2002-03) round of the Nepal LSMS.

As discussed further in section 4, there are few rigorous micro-econometric studies on the determinants of fuelwood demand at the household level, with some notable exceptions (e.g., Pitt (1985), Foster and Rosenzweig (2003), Chaudhuri and Pfaff (2004)). Contrary to most existing literature, we estimate wealth and substitution effects associated with increases in different assets. Owing to lack of longitudinal data, we examine cross-sectional variations in household firewood collections with ownership of different assets. Our analysis addresses a number of methodological problems associated with endogeneity, measurement error, omitted variables and endogenous censoring.

The most important problem is endogeneity of income or consumption, the most commonly used measures of household living standards. Given the absence of markets for firewood, and the importance of self-employment in these settings, household decisions concerning labor supply, consumption and firewood collection are made jointly. There are many possible unobserved household traits that affect both consumption and firewood collection that could bias estimated Engel elasticities. In addition, both income and consumption are prone to significant measurement errors, especially in a rural society dominated by farming and livestock related occupations. Reliable instruments for income and consumption that do not affect firewood collections are rarely available.

An additional problem is posed by unobservability of the cost of using firewood, owing to the lack of firewood markets. Very few households in our sample purchase firewood, and sales of firewood are equally rare.[9] Household decisions concerning the amount of firewood to be collected interact with household decisions concerning the allocation of labor available for self-employment between household and productive tasks. This implies that the economic cost of firewood cannot be separated from other household characteristics, incomes or consumption. Conventional tools of demand analysis that assume exogeneity of income, consumption and prices are therefore inapplicable.

We proceed on the premise that endogeneity and measurement error problems are less acute for underlying household assets (land, livestock, household size, education etc.) than income or consumption. Based on a model of household decision-making concerning labor supply, fuel choice and consumption for a given composition of assets owned, we develop two estimation strategies. The first (called the semi-structural (SS) approach) aggregates stocks of different assets into a single scalar measure of wealth (called 'potential income'). For this purpose we estimate a household production function, following the approach of Jacoby (1993) to overcome problems with endogeneity of labor supply. Apart from allowing us to estimate household potential income as the measure of wealth, this yields an estimate of household shadow wages which can be used to value the opportunity cost of time spent collecting firewood.

[9]See Cooke (1998) for similar observations concerning Nepal in the 1980s. Amacher *et al* (1996) attempt to explicitly incorporate firewood sales and purchases in household decision making. However, as they themselves acknowledge, they observe many more firewood purchases than sales, a discrepancy that can be attributed either to sampling bias, or misreporting of occasional activities. In India, the 1993-4 NSS shows that only 13% of the fuelwood consumed throughout the country is purchased (Arnold *et al*, 2003).

At the second step these are used as measures of household wealth and collection cost (interacted with reported firewood collection times) used to predict firewood collections.

The second estimation strategy (we call the reduced form (RF) approach) relates firewood collection directly to the entire vector of household assets, and their interaction with collection times. While the results of this approach are more complex and harder to interpret than the SS results, they are more reliable owing to avoidance of errors in estimating potential income and shadow wages. Moreover, it avoids the assumption implicit in the aggregation procedure underlying the SS approach that the wealth effects of each asset are proportional to their respective effects on household income. Wealth effects could differ from income effects in a heterogenous fashion if different assets are associated with distinct occupations, locations of work, or networks of co-workers, which affect awareness of household members concerning health effects of firewood *vis-a-vis* alternate fuels, or accessibility to the latter.[10]

Other econometric issues pertain to omitted variables, functional form and endogenous censoring. Geography or climate variations may jointly affect firewood availability, asset ownership and living standards. We control for such village-specific characteristics with village fixed effects, effectively focusing on intra-village varia-

[10]Inclusion of the reduced form estimates represents the most important difference from earlier versions of this paper. The earlier versions also suffered from data errors in measuring consumption. Specifically, the LSMS earlier data set was characterized by absence of data on consumption for a significant fraction of households;these missing values had been mistakenly replaced by zeroes. However, this affected only the simple Engel relationship reported in the earlier versions, not the SS results.

tions of firewood collections with household wealth. This also controls for factors such as inequality or social norms that have been argued to be important determinants of common property resources use.[11] We control for various other household characteristics available in the LSMS data, such as household demographics.

To allow for non-linear wealth effects (postulated by EKC or energy ladder theories) we adopt a double-log-quadratic specification of wealth effects. Approximately one-fifth of our sample do not collect any firewood at all. This necessitates controlling for endogenous censoring, which creates econometric complications owing to the simultaneous control for village fixed effects. For this purpose we use the semiparametric trimmed least absolute deviation (TLAD) estimator proposed by Honore (1992) for panel regressions with censoring.

For the 1995-96 LSMS, we find different assets exhibit distinct wealth and substitution effects. This heterogeneity complicates the interpretation of the evidence, in terms of the association between any single measure of 'living standards' and firewood collections. If we use per capita consumption as the measure of living standards and the observed asset stocks at different percentiles of the distribution of per capita consumption, the effect of rising living standards depends on which assets account for the rise. Collections do not respond much to landownership, as wealth and substitution effects tend to neutralize each other. They rise significantly with respect to livestock owned, owing to a positive substitution effects (which reflect complementarity between livestock grazing and firewood collection) and negligible wealth effects.

[11]In a related paper (Baland et al (2007b), we have investigated the role of these village-level factors in Nepal, using the same data-set.

Collections exhibit an EKC-like inverted-U pattern with respect to education and non-farm assets, with turning points located at the median and top deciles of the distribution respectively.

The evidence thus firmly contradicts the poverty environment hypothesis, irrespective of the underlying source of variations in living standards. Those in the bottom half or quarter of the population defined by per capita consumption collect significantly less than those in the rest of the population, irrespective of the specific asset which accounts for the variation in consumption standards. This is also reflected in the raw nonparametric relationship between per capita consumption and collections, which exhibits a significant positive association throughout the entire distribution, except at the very top. For the median household, the reduced form estimates imply that a 10% simultaneous increase in all four assets (land, livestock, education, non-farm assets) is associated with a 6.8% rise in firewood collection. Even in the top decile, such a rise in assets would raise collections by 4.6%. Similar patterns prevail in the 2002-03 LSMS sample as well.

In contrast, we obtain mixed evidence concerning EKC, with the results depending on asset composition and time period. No inverted-U effects arise if living standards rise owing to increased ownership of assets associated with traditional occupations such as land or livestock. They do appear for education, and at the very top end of the distribution for non-farm assets, in the 1995-96 sample. In the 2002-03 sample, no inverted-U patterns arise with respect to any asset: rising education lowers collections while rising non-farm assets raise collections throughout the distribution.

These results indicate the shortcomings of any approach that attempts to measure the environment-development relationship by relying on a single scalar measure of wealth or living standards. They suggest that assessments of the effect of growth or poverty reduction on forest degradation need to incorporate the source of such growth and attendant changes in asset composition.[12] The estimated net elasticity of collections for the median household with respect to a rise in livestock assets in the 1995-96 sample wa 0.50, in contrast to 0.01 for education and 0.23 for non-farm assets. If growth is associated with rising education and non-farm assets, the pressure on the forests is likely to increase by much less, compared to growth based on traditional assets such as livestock. Between 1995-96 and 2002-03, average education and nonfarm assets grew while livestock holdings fell. Presumably this was part of the reason that firewood collections per household fell between these dates, despite a reduction in average collection times.

Other implications of our results concern effects of household size and rising collection times. We find evidence of considerable household economies of scale, suggesting that the effect of rising population on forest pressure will depend on whether those take the form of rising size of households as against an increase in the number of households. Using our estimates to calculate the reciprocal impact on living standards of an increase in collection times by one hour per bundle (a 20% increase over current collection times), we find a relatively small effect, of the order of less than 2% of the value of consumption for all households. This implies that local collection externalities are not large. Consequently policy interventions need to be motivated by ecological

[12]Of course, the use of cross-sectional elasticities to project the effects of growth is fraught with many problems, so these implications are purely illustrative. A more definitive analysis of growth effects will need to use longitudinal data.

or non-local spillover effects.

Section 2 provides the theoretical framework underlying our regression specification, and discusses underlying assumptions of our empirical methodology. Section 3 presents the empirical results for the 1995-96 LSMS data, as well as for the subsequent 2002-03 round. Section 4 discusses related literature, while Section 5 concludes.

2 Theory

We consider a household with a utility function for a representative member which depends on consumption of two forms of energy, leisure and other consumption goods

$$U = U(\frac{C}{n}, F, \frac{\theta G + F}{n}, l) \tag{1}$$

where C denotes total household consumption of goods, n is household size, l denotes per capita leisure, F denotes firewood collected, and G denotes alternate energy sources (such as gas) purchased on the market. The household needs energy for heat and for cooking. Heat is provided by consumption of firewood alone, and is a household public good; hence the second argument of (1) represents heat energy consumed by household members. The third argument represents per capita cooking energy, which is available from firewood and gas at a constant rate of substitution θ. We shall abstract from issues concerning intra-household allocation of consumption and work, assuming all members are identical and are treated equally.

Household income is given by

$$I = Y + \bar{Y} \tag{2}$$

the sum of self-employment income Y and exogenous fixed income $\bar{Y}$ consisting of pensions, salaries of permanently employed members and wage employment earnings. Self-employed income is the value of household production, a Cobb-Douglas function of total self-employed labor hours L and productive assets owned by the household. There are four assets: land, livestock, education and non-farm business assets. Letting A_i represent the asset stock of type i,

$$Y = \delta \left(\prod_i A_i^{\alpha_i} \right) L^{\beta} \tag{3}$$

where α_i denotes the elasticity with respect to asset i, β is the elasticity with respect to labor applied, and δ is a measure of total factor productivity. To simplify the analysis we shall not model occupational choices and incomes generated from different occupations separately: (3) represents their joint impact. We shall proceed on the assumption that asset holdings and household size are exogenously given, while allocation of labor and self-employed earnings are endogenous.

Less than 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 shall therefore ignore market transactions in firewood markets altogether. Hence firewood used must be entirely collected by the household itself. To the extent that firewood is likely to be collected and sold by poorer households to richer ones, the exclusion of such transactions will tend to underestimate the elasticity of firewood consumption with respect to living standards.

The cost of using firewood therefore corresponds to the opportunity cost of time involved in collecting it.[13] The time spent collecting firewood t^f varies across households

[13]Note that there is no need to control for the stock of fuelwood available in the village, as the

within a village corresponding to their respective principal occupations, owing to differing degrees of substitutability between those activities and collection of firewood. Those principally grazing livestock will incur lower incremental collection times, owing to the proximity of forests to grazing lands and the ability of grazers to collect wood at the same time that the animals are grazing. Those with more education or non-farm business assets are likely to be engaged in occupations that take them outside the village. For them collecting firewood requires greater times diverted from their principal occupation. Since occupational patterns will depend endogenously on the composition of assets owned, collection times satisfy the following relationship:

$$t^f = t^c(\gamma_0 + \sum_i \gamma_i A_i) \tag{4}$$

where t^c represent the time taken to collect firewood for a household with no assets, and γ_i measures the degree of substitutability between the activity associated with asset i and firewood collection.

The extent of household labor allocated to self-employment is then given by

$$L = n^P(\bar{l} - l) - t^f F \tag{5}$$

where n^P denotes the number of adults (using an adult equivalent scale of 0.25 for children) available for self-employment, and $\bar{l}$ is the total number of hours available per equivalent adult (16 hours per day). And letting p_G represent the price of gas, the household budget constraint is:

$$C + p_G G = I. \tag{6}$$

impact of these on fuelwood decisions will be fully captured by the collection time (for a similar approach, see also Dewees (1989) and Cooke *et al* (2001)).

The household maximizes utility (1) by choosing gas, firewood, leisure and consumption expenditures subject to (5,6), taking assets, fixed income, demographics and the time taken to collect firewood as given. This yields the following first-order condition for firewood (using equations (3,5,6)):

$$U_2 + \frac{1}{n}U_3 = U_1 \frac{1}{n}\frac{\partial Y}{\partial L}t^f. \tag{7}$$

The right-hand side can be interpreted as follows: U_1 represents the income effect, $\frac{1}{n}$ a household size effect, while $\frac{\partial Y}{\partial L}t^f$ is the cost of collection effect, equal to the product of collection time t^f and shadow wage: $\frac{\partial Y}{\partial L} = \beta\delta\left(\prod A_i^{\alpha_i}\right)L^{\beta-1}$.

These first order conditions take a particularly simple form when the utility function is additively separable, as in the case of a linear expenditure system (with $\beta_c, \beta_h, \beta_e, \beta_l$ denoting elasticity of utility w.r.t. $C, F, F+\theta G, l$ respectively, and respective subsistence per capita requirements by $\underline{c}, \underline{f}, \underline{e}, \underline{l}$):

$$\frac{\beta_h}{F-\underline{f}} + \frac{\beta_e}{F+\theta G - n\underline{e}} = \frac{\beta_c}{C-n\underline{c}}\left(\frac{\partial Y}{\partial L}t^f\right) \tag{8}$$

$$\frac{\beta_e}{F+\theta G - n\underline{e}} \leq \frac{\beta_c}{C-n\underline{c}}\frac{p_g}{\theta} \tag{9}$$

with equality if $G > 0$, and,

$$\frac{\beta_l}{l-\underline{l}} = \frac{\beta_c}{C-n\underline{c}}\left(\frac{\partial Y}{\partial L}n^P\right). \tag{10}$$

Combining these, we obtain the following equation for firewood collected:

$$\frac{\beta_h}{F-\underline{f}} = \frac{\beta_c}{C-n\underline{c}}\left(\frac{\partial Y}{\partial L}.t^c(\gamma_0 + \sum_i \gamma_i A_i) - \frac{p_g}{\theta}\right) \tag{11}$$

if $G > 0$. On the other hand if $G = 0$, equation (10) is replaced by:

$$\frac{\beta_h}{F - \underline{f}} + \frac{\beta_c}{F - n\underline{e}} = \frac{\beta_c}{C - n\underline{c}} \left(\frac{\partial Y}{\partial L} . t^c (\gamma_0 + \sum_i \gamma_i A_i) \right) \tag{12}$$

This tells us that F is increasing in consumption (C) — the income effect — and decreasing in the collection cost $\left(\frac{\partial Y}{\partial L} . t^c (\gamma_0 + \sum_i \gamma_i A_i)\right)$. Besides it is also a function of household size n and the price of gas p_g. This generates *our semi-structural form (SSF) specification*: aggregate firewood of the household is a function of consumption (or some measure of wealth), household size and collection cost (the product of shadow wage and collection time). In this specification there is no need to include household self-employed labor stock n^P as its effect is already included in consumption. This implies a regression equation specified as:

$$F = f(C, \frac{\partial Y}{\partial L} * t^c (\gamma_0 + \sum_i \gamma_i A_i), n, p_g) \tag{13}$$

The main problem in estimating a regression based on (13) is that the shadow wage is endogenously determined, as well as consumption. Omitted household characteristics such as industriousness, location or illness could affect consumption, shadow wages and firewood collections, resulting in biased estimates.

To address the endogeneity issue, a possible strategy is to measure income by the household *potential income*, defined as the self-employment income that the household would earn if it were to fully utilize its labor stock:

$$W = \delta \left(\prod_i A_i^{\alpha_i} \right) (n^P \bar{l})^\beta$$

Potential income is then independent of household decisions concerning labor allocation, and depends only on exogenous asset stocks. So it can be used as a measure of wealth that replaces consumption. This also removes sources of transitory shocks and measurement error in reported consumption and self-employed income. However, calculation of potential income requires estimates of elasticities of the production function.

The first stage of the SS approach thus estimates the household production function. As labor choices are endogenous, we will follow Jacoby (1993) and instrument labor hours by household size (the number of adults available for self-employment). This ignores the possibility that more productive households might attract relatives to join the household. Moreover, the exclusion restriction rules out the possibility that controlling for total hours employed, a larger household may be more productive, by taking better advantage of the division of labor or complementarity of skills across members. This instrumentation strategy arguably constitutes an improvement on an estimation directly based on labor hours, but may not completely solve the problem.

At the second stage of the SS approach, the estimated elasticities of the production function are used in conjunction with assets to estimate potential income and shadow wage of each household. The problem with endogeneity of shadow wages remains, however, as it is computed at observed labor allocation decisions. In addition, the use of estimates of the production function parameters inevitably creates some errors of measurement in potential income and shadow wages, with attendant attenuation biases. They may also involve aggregation biases if the assumption underlying the aggregation (that the wealth effect generated by different assets should be proportional to their respective income effects) is not valid.

These problems are avoided in the reduced form approach, which relates consumption and shadow wages back to household characteristics. Consumption is a function of household assets (which includes household labor stock n_P), fixed income ($\bar{Y}$) as well as various prices and costs ($p_g, t^c, t^c * A_i, ...$). The shadow wage is a function of household assets and collection costs. Combining these, we obtain the (RF) specification in which F is expressed as a function of household assets (including n_P), household size (n), collection costs (t^f), and price of gas (p_g). Specifically, we substitute in equation (13) for consumption C and shadow wage σ to obtain

$$F = f(C(A_1, ...A_n, n_P, \bar{Y}, p_g, t^f), t^f * \sigma(A_{1,...}A_n, n_P), n, p_g) \tag{14}$$

where it may be recalled t^f depends on household assets as represented by (4). To keep the analysis tractable, we use the following approximation for the cost of collection as a function of household characteristics, which ignores interactions between n_P and assets, and higher-order terms in assets:

$$t^f * \sigma(A_{1,...}A_n, n_P) \simeq \eta_0.t^c + \eta_1.(n_P * t^c) + \sum_i \mu_i(A_i * t^c) \tag{15}$$

The cost of collection for household i thus depends on the village average collection time (which will be subsumed in the village fixed effect), and interactions between average collection time and key determinants of shadow wages: stock of household labor available for self-employment and assets owned. It ignores the effects of interactions between various assets, and between each asset and household size. This is a disadvantage of the RF specification, apart from its greater complexity compared to the SSF specification. Accordingly we shall present estimates corresponding to both approaches.

Note also that in the RF specification we would expect the sign of η_0 to be negative, as it represents the effect of higher collection times on average. This effect is likely to be more pronounced for those with higher shadow wages, and those owning assets related to occupations not complementary with firewood collection. Hence the interaction effect η_1 of collection time with household labor stock is expected to be positive, as well as μ_2, its interaction with livestock owned. Interactions μ_3, μ_4 with education and nonfarm assets are expected to be negative, as they are expected to be correlated with non-farm employment.

An additional issue concerns choice of functional form, which is necessarily somewhat *ad hoc*, involving issues such as whether variables should be measured in natural or logarithmic units, whether a linear or quadratic approximation be used, and ways of limiting multicollinearity problems. For ease of interpretation of estimated coefficients, we measure all variables in logs. We include second-order terms in the wealth effects (log consumption or log assets) in order to capture possible EKC effects.[14] In the reduced form both n_P and n enter, two measures of household size which are likely to be highly positively correlated. Hence after controlling for household size n and fixed income $\bar{Y}$, we include the log of the ratio of self-employed labor stock to household size $(\frac{n_P}{n})$ as an additional household asset, in order to reduce collinearity problems. With regard to the substitution effect, however, we use the interaction of self-labor stock with collection time, as indicated by the theory. For the same reason, all variables are measured as household aggregates rather than per capita magnitudes.

[14]A purely log-linear specification of the wealth effect would impose a monotone relationship between wealth and firewood consumption, preventing the possibility that wood may be a superior good at low levels of wealth and an inferior good at higher levels. We stop short of a full translog specification, and drop interactions between the log of various assets or between asset measures and cost measures, for the sake of parsimony and because these interactions are not easily interpreted.

Finally, unobserved village variables such as the size of the forest stock, collection time, climate, village norms, urbanization or access to fuel substitutes can jointly affect income and collection activities. We use village fixed effects to control for such unobserved village attributes. With one-fifth of the sample not collecting firewood at all, we need to incorporate endogenous censoring. This introduces nonlinearity in the model so that the fixed effects cannot be differenced out. A fixed-effects tobit model with village dummies is difficult to estimate due to the large number of villages. Similarly, a random-effects tobit model with endogenous regressors, as suggested by Wooldridge (2002, p.540), is also unsuitable due to the lack of reliable instruments at the village level. Hence we use the semiparametric TLAD estimator proposed by Honore (1992) for censored data with fixed effects.

Problems that we cannot address owing to the nature of the data include the following. The amount of firewood collected is measured in terms of the number of 'bharis' or headloads that the household report collecting. As the size of a headload varies across individuals, this introduces a potential bias. It is possible that richer households are better fed tend to carry larger bharis, resulting in an underestimate of the impact of living standards on actual firewood collection. Additionally, households confronted with longer walking times carry lighter or smaller headloads. The impact of collection time on the amount of firewood taken may thus be under-estimated.

Collection time is also based on individual reporting by the household, and may thus vary with various characteristics. To partially address this problem, we compute the average of individual collection times at the village level, and use the latter as a more 'objective' measure of collection time. The other advantage of this is that this measure can also be used for villagers that do not collect firewood. This procedure is valid as long as villages are not too dispersed so that all villagers face the same distance to the forests.

Other problems arise from our assumption that all household members are identical with regard to their skills and are thus perfect substitutes in production. In particular, it implies that all members face the same shadow wage in collecting firewood, and share collection tasks equally. This ignores the possibility of specialization of tasks within the household, with resulting disparities in shadow wages across different members.

3 The Determinants of Firewood Collection in Nepal

3.1 Descriptive Statistics

The World Bank Living Standards Measurement Survey (LSMS) for Nepal interviewed households concerning their production and consumption activities for the year 1995-96. The subsequent LSMS was carried out in 2002-03 and we examine the robustness of results for that data set as well later in the paper. The 1995-96 survey covered 274 wards (villages) in rural areas. We focus only on villages in which there is at least one household collecting. After dropping households and villages with incomplete or missing data, we are able to use data for 2314 households in 205 villages.[15]

Table 1 shows that wood fuel is the main source of energy for cooking and heating for 81.8% of the households (the other leading sources being cowdung (9.6%) and leaves or straw (3.3%)). Only 5.2% of the households use kerosene or gas as the primary source of cooking or heating fuel. The pattern for villages in which no firewood is collected is very different, as the three major sources of energy there are cowdung (42.1%), kerosene (26.2%) and leaves (12.9%).

Tables 2 and 3 present averages of household and village characteristics in the sample. An average household collects 79.2 bharis (i.e., a headload) or bundles of firewood per year (which corresponds to 23.0 bharis per capita per year), while one-fifth of all households do not collect any firewood at all. Households mentioned adults as the principal collectors of firewood, and females somewhat more important than males in this respect.[16] The average time reported to collect one bundle of firewood was five hours, implying a total of about eight hours per week spent collecting firewood for the average household.

In 1993 the government of Nepal introduced a community forestry scheme, handing over forest areas to be managed by local communities.[17] Table 3 shows that in our

[15] From the initial set of 2440 households, we lose those who report non-farm business incomes without reporting their asset values, leaving us with 2314 households.

[16] The average number of adults collecting per household was 1.2, of which 0.69 were females. Cooke (1998) and Adhikari (2002) similarly find a high involvement of women and children in collecting firewood in Nepalese households.

[17] 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

sample, 9% of the households reported collecting from a community forest and 33% (68 out of 205) of the villages have at least one such household in the sample. Unfortunately the LSMS household questionnaire did not include a direct question about membership of the household. Consequently we could not include this information among the set of household characteristics; the use of village fixed effects enables us to ignore its impact at the village level.

The mean annual consumption for a household was Rs. 37613. Given that the average household size of five members (in adult equivalent units, with members of age below 16 being counted as half an adult), the corresponding annual per capita consumption was approximately $169 (in 1995-96 prices). The proportion of households with consumption levels below 1$ per day per capita was 92%, indicating high levels of poverty. The majority were engaged in self-employed agricultural activities and livestock rearing: 59% did not have a non-farm occupation. The principal productive assets consisted of cultivated land, livestock and nonfarm business assets.[18] Educa-

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. 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. 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, and that the effect of the forest user groups varies substantially with the type and source of external development assistance in different parts of Nepal.

[18]We consider only big livestock in our analysis, as small livestock (goats and sheep) turned out to play an insignificant role in all specifications.

tion levels were low: in 46% of the households, none of the adults had any education at all.

The villages vary considerably with regard to elevation, ranging from 191 to 17460 feet above sea level. The low lying Terai region, usually defined by an elevation of up to 1000 ft above sea level, experienced the greatest deforestation since the 1950s. Table 2 differentiates the two regions. 68% of the households in our sample are from the non-Terai region. The two regions do not differ significantly with respect to average consumption, livestock ownership or fraction of household employment allocated to farm occupation. Households in the Terai cultivate less land, are more educated and have larger households, while they tend to have less non farm business assets. Firewood collections differ a lot across the two regions as households collect an average of 45.7 bharis in the Terai as against 94.7 bharis in the non-Terai.[19] The average collection times are approximately the same in both regions, but fuel needs differ a lot between the two: the Terai benefits from a sub-tropical climate, with an average temperature well above 20°C (and above 15°C year round), while the non-Terai is characterized by cool dry temperate and alpine climates, with temperatures ranging from -5°C to 25°C over the year. Given these differences, we will provide separate estimates of the reduced form for the two regions.

[19]We ignore all villages where no collection of firewood was reported, a more frequent occurrence in the more deforested Terai. The true disparity between the two regions is therefore even greater.

3.2 Simple Engel Curves

The first step in the empirical analysis is estimation of the household production function (equation (3)). Table 4 shows the estimates obtained with village fixed effects and labor hours instrumented by number of adults in the household that are not in permanent employment, following the approach of Jacoby (1993).[20] This is based on the assumption that (conditional on household assets) household size is not correlated with unobserved attributes that may affect its income. This assumption may be violated if more households with higher (unobserved) productivity tend to attract more members of the extended family to join them. In rural Nepal, however, it is the custom for the elderly to live with their adult children: in our sample only 2% of people above the age of 65 live by themselves. Moreover, the correlation of labor stock available for self-employment with per capita self-employment income is -0.06, so it is unlikely that higher income households tend to attract non-members of the nuclear family.

Table 4 shows an estimated elasticity with respect to labor hours of 0.6. This implies a shadow wage was 60% of the average product of labor (measured by self-employment earnings per hour). The elasticity with respect to land and livestock vary between 0.2 and 0.3, while with respect to education and non-farm assets were 0.1 and 0.06

[20] The sample used for this regression excludes households with negative values of self-income (owing typically to large business losses) and with no self-employment. The estimate is thus based on a smaller sample of 2100 households. However, we can thereafter predict the shadow wage of 2190 households with positive self-employment labor. In the instrument used for labor hours, we do not include the number of children in the household, since fertility decisions may be correlated with unmeasured household attributes relevant to its productivity.

respectively.

The estimated production function is used to calculate the shadow wage and potential income of each household. Table 5 presents averages of the estimated values of potential income and shadow wage, along with annual consumption and income. Average consumption exceeds average income slightly, and the latter is about one-third of potential income, reflecting partial utilization of labor stock available for self-employment. However, variations in potential income correspond closely to variations in consumption within villages. Figure 1 displays a Gaussian kernel regression between standardized deviations of potential income and household consumption expenditures (bandwidth=0.25) from their respective village means.[21] It shows that the relationship is increasing, and approximately linear. Hence potential income seems a reasonable proxy for living standards variations within villages.

Table 5 also indicates that the average shadow wage is equal to Rs 7.8 per hour, varying from Rs 3.3 per hour at the 10th percentile to Rs 13.8 per hour at the 90th percentile. It is much lower than the village average casual wage, but marked by a similar dispersion. One source of divergence between reported market wages and the value of time arises due to seasonal fluctuations in the labor market. Wage employment arises for a few months in the year (e.g., during harvesting and sowing seasons), when market wage rates rise above the value of time in household production. In our sample all households participating in wage employment were also involved in home production. For this reason reported market wage rates (which pertain to the high

[21] Potential income and consumption are measured in natural units. Deviations from village means are divided by the standard deviation to yield the standardized deviations.

demand periods) turned out to be substantially above shadow wages (which pertain to year-round labor). Hence wage employment earnings are intra-marginal; the margin of labor-leisure choices operate solely with respect to home production, which provides the relevant measure of opportunity cost of time spent collecting firewood.[22]

Figure 2 presents a non-parametric regression between (standardized) deviations of household firewood collection and consumption expenditures (using a Gaussian kernel with bandwidth= 0.4) from respective village averages. The relationship between the two is rising, except at the top end where it starts falling, suggesting an EKC pattern. The turning-point is however located at the very top end of the distribution, corresponding to the 97th percentile of the distribution. Figure 3 shows the corresponding relationship between firewood collection and potential income. Here the relationship tends to rise throughout, except at the very top end of the distribution located above the 99th percentile.

Table 6 presents quadratic regressions of firewood collection on potential income and consumption respectively, both with and without village fixed effects. These do not control for other household characteristics. Columns (6.1) and (6.3) report OLS regressions that do not incorporate either endogenous censoring or village effects. The other two columns report TLAD regressions with village fixed effects. All regressions display an EKC pattern, with significant positive first-order and negative quadratic effects. The turning point is typically located above the 95th percentile. Columns (6.2) and (6.4) imply an elasticity of 0.3–0.5 of collections with respect to poten-

[22]Another source of divergence between the two measures is the existence of non-pecuniary costs for family members, especially women and children, to work outside the home or own farm.

tial income and consumption respectively. These are consistent with various studies (reported in Beck and Nesmith (2001) and Jodha (1986)) in India and Africa, indicating a larger *relative* reliance of poor households on environmental common property resources, compared with wealthier households.

3.3 Firewood Collection: Detailed Results

Table 7 presents estimates of the SSF specification, based on equation (12). Column 7.1 presents the estimates using the estimated potential income of each household as a measure of wealth. Columns 7.2 and 7.3 show how the results are affected when they are replaced by annual consumption and income respectively. The collection cost is measured using the shadow wage predicted by the production function given in Table 4, interacted with the average collection time at the village level and also, as suggested by the model, with various assets owned by the household.

The results presented in Table 7 separate the effect of rising assets into wealth and cost-of-collection effects. Estimated wealth effects are statistically insignificant at the 10% level when potential income is used as the measure of wealth. However, they are significant when consumption and income are used instead. Cost-of-collection effects do not differ much across different measures of wealth. Rising collection time itself (interacted with the shadow wage) has a significant negative effect. As expected, livestock ownership lowers this effect significantly, while education raises it. Land and non-farm assets do not affect the collection cost effect. Finally, household size effects show some evidence of household economies of scale.

The insignificance of the wealth effects in column 7.1 could result from attenuation bias owing to measurement error in potential income. It also aggregates the effects of different assets into a single measure of wealth. We thus turn to Table 8 which presents the RF estimates, using each asset separately. Column 8.1 shows the estimates for the entire sample. Now we find significant inverted-U wealth effects with respect to education and non-farm assets, and a positive wealth effect with respect to land. Hence the reduced form specification generates significant wealth effects, suggesting that the insignificance of the SSF estimates may have resulted from a combination of attenuation and aggregation biases. Indeed, we find the relative direct effects of different assets are not proportional to their respective effects on income as indicated in Table 4. Increased education or non-farm assets seem to generate larger wealth effects on collections compared with their relative effects on household income. This suggests that the SS estimates were subject to aggregation bias.

In the reduced form specification, we cannot directly estimate the impact of collection time for a household with no asset, as it is captured in the village fixed effect. The substitution effects that can be estimated are those interacted with asset ownership. These effects are positive for the interaction with livestock, confirming that grazing is a complementary activity to firewood collection, and negative for the interaction with land and education. That land is significant in this specification but not in the semi-structural form can possibly be explained by the fact that households with a larger endowment in land have a higher shadow wage. Since the reduced form does not include an interaction with the shadow wage, the impact of land on the costs of collection is captured by the interaction of land with collection time. In the semi-structural form, it is indirectly captured by the shadow wage.

While the reduced form estimates are more reliable than the SS estimates, they are more complex to interpret. Tables 9A and 9B show implied elasticities of firewood collection with respect to changes in each asset. Table 8 shows significant quadratic effects with respect to education, nonfarm assets and household assets. Hence elasticities with respect to these assets need to be computed at different holdings of the asset. Table 9A shows the wealth effects generated by these at different percentiles of the distribution associated with each asset respectively. For instance, the elasticity with respect to education is assessed at 10th, 50th, 90th, 95th and 97.5th percentiles of the education distribution. Only coefficients significant at 10% in Table 8 are used, the rest are set equal to zero.

An inverted-U pattern arises both for the wealth effect and the total effect with respect to education, non-farm assets and household size. For land a positive wealth effect outweighs slightly a negative substitution effect, to yield a small positive elasticity. Livestock does not generate a significant wealth effect, but is associated with a significantly positive substitution effect, resulting in a net elasticity of +0.5. With regard to education we see the wealth effect is positive at the median but turns negative somewhere between the 90th and 95th percentile. The substitution effect is significantly negative throughout. Hence the net elasticity which is +.01 at the median is significantly negative for the top 10%. Non-farm business assets do not generate a significant substitution effect, while the wealth effect follows an inverted-U: rising at the median and falling among the top 10%. A similar pattern arises for household size.[23]

[23]Somewhat surprisingly collections are falling with size at the top end of the size distribution. This is no longer the case in Table 9B below.

The results in Table 9A pertain to the elasticity expressed at different points of the range of each asset separately. For instance, the elasticity with respect to education as assessed at different percentiles of the education distribution, not that of household standard of living. To assess the validity of the poverty-environment hypothesis or the EKC, however, requires us to express the implied elasticity at different levels of standard of living, i.e., use information concerning the pattern of asset holdings across different percentiles of the distribution of per capita consumption, and evaluate elasticities corresponding to those asset stocks. Column 2 of Table 9B shows (log values of) average holdings of education, nonfarm assets and household size over a 5% band centered at different percentiles of the household per capita consumption distribution.[24] We see that educational status is not monotone in per capita consumption: households with the highest consumption standards have less education than those at the 90th percentile, for instance.

The resulting elasticities are reported in the last three columns of Table 9B. The pattern turns out to be qualitatively similar to that in Table 9A. Results with respect to land and livestock are unchanged owing to the absence of significant nonlinearities. With regard to education, the elasticity tends to be significantly smaller, and the inverted-U now exhibits a turning point slightly below the median, rather than at the top decile. This owes to the fact that the median household defined by consumption standards has a higher level of education than the median level of education in the

[24] For instance, for the 50th percentile, we average asset holdings over households located between the 47.5th and 52.5th percentiles. We do this to ensure that the resulting elasticity estimate is not driven too much by the specific asset positions of a particular household located exactly at the median.

population. With regard to non-farm assets however, the turning point continues to appear at the 95th percentile. Hence EKC patterns emerge with respect to assets associated with non-traditional occupations, not with respect to traditional ones.

Finally, household size in Table 9B exhibits a positive and increasing elasticity throughout the distribution, since household size is monotonically decreasing in per capita consumption. Firewood collection exhibits decreasing returns in household size, as the elasticity is uniformly below one. In other words, per capita firewood collections decrease as the household gets larger, a feature which may partly be attributed to the public good nature of heating energy. These suggest the effect of population growth will depend on the nature of that growth: they will be substantially larger if it take the form of more households of the same size, rather than an increase in household size. Division of larger households into smaller ones is likely to result in loss of household economies of scale and raise total collections at the level of the village.

Columns 8.2 and 8.3 in Table 8 show reduced form estimates on the Terai and non Terai subsamples respectively. They are consistent with the ones obtained for Nepal as a whole, while firewood collection is more sensitive to asset variations in the Terai regions. In the non-Terai region no collection cost effects appear to be significant, and wealth effects are smaller and less significant. This is what one would expect: there is greater need for heat in winter in the non-Terai, awareness and availability of alternate fuels is lower, and non-traditional occupations are less frequent.

3.4 Reciprocal Impact of Degradation on Living Standards

A major impact of forest degradation for neighboring populations is the resulting increase in firewood collection time. At the local level, this is the main source of the local externality: higher collections by some household will raise collection times in the future for all villagers. In this section we measure the magnitude of this externality, as implied by our previous results. The welfare effect of a small increase in collection time can be approximated (using the Envelope Theorem) by calculating the shadow value of the increased time necessary to collect the amount of firewood actually collected prior to such an increase. This represents an upper bound of the cost to the household, since it can adjust collections as collection times rise.

Consider an increase in collection time per bundle by one hour, which represents a 20% increase.[25] An average household collects 79 bharis per year. At the median shadow wage of Rs. 6.37 per hour, an increase by one hour in collection time represents an income loss of Rs 503.2 per year. Given consumption expenditures of Rs 30675 per year for the median household, this corresponds to a 1.6% drop in consumption. The magnitude of the local externality on the average household is thus quite small.

The low average impact may, however, conceal large distributional effects. The distribution of the effect is not *a priori* obvious: poor households have a lower shadow wage, but also lower consumption expenditures and potential income. To check this we compute the proportional income loss for a household in the tenth decile, by using

[25]This can be compared to the figure obtained in Baland et al (2007a) in the Indian Himalayas, where the increase in collection time over the past 25 years was estimated to be 1.7 hours, from 4.4 to 6.1 hours per bundle.

the shadow wage and consumption expenditures corresponding to this decile. The proportional income loss thus computed is equal to 2%. The corresponding figure for the top 90% is equal to 1.4%. The impact of degradation on living standards is thus relatively uniform and remains small across the entire range of households. In Baland et al (2007a) we find a similar result for the Indian Himalayan region as well. This may explain the lack of concern by villagers about the degradation of village forests. It also suggests that the arguments for policy interventions need to be based on the importance of non-local externalities or ecological effects, such as erosion, biodiversity, landslides and siltation of downstream rivers.

3.5 Determinants of Firewood Collections in 2002-3

Another Living Standard Measurement Survey was administered in Nepal in 2002-3, which drew a different sample of households and villages. We examine how our results change for this data-set. We again focus on the villages in which at least one household collected firewood. After dropping households with missing observations, we were left with a sample of 3159 households in 282 rural villages. Firewood became less important: 75% of the households list firewood as their main source of fuel in collecting villages, and the average amount collected is 64 bharis per household, compared with 82% and 79 bharis per household in 1995-96. In villages where no collection occurs, gas became the primary source of fuel for 54 % of the households, compared with only 9.4% in 1995-6. The mean collection time was 3.6 hours per bharis, much lower compared to 1995-6. This may have been caused partly by the vast expansion of the community forestry program in Nepal: 24% of the households reported collecting firewood from a community forest, as compared to 9% in 1995-6.

Average consumption expenditures (measured in 1995 rupees) did not change substantially, but incomes were higher, particularly in the non-Terai area. In terms of assets, the average amount of land cultivated was 5.04 hectares, similar to the 1995-6 level. Mean livestock ownership decreased to 2.63 cows and buffaloes (as against 3.78), while average total adult education in the household increased from 5.92 to 8.18 years. The value of non-farm business assets more than doubled at 1995-96 prices. Household size became slightly smaller (5.13 members). As expected from the large growth in modern assets, a larger proportion of time (32%) was allocated to non-farm occupations.

Figure 4 depicts the simple (nonparametric) Engel curve between collections and consumption expenditures for 2002-03. The pattern is similar to that in 1995-96 (shown earlier in Figure 2): it is concave and increasing except at the very end where we observe a turning point, corresponding to the 96th percentile of the distribution. Quadratic regressions using potential income, consumption expenditures or actual income confirm this pattern.

Table 10 reports the reduced form estimates of the firewood collection regression for 2002-03, using the same specification as Table 8. Tables 11A,B report the implied elasticities, analogous to Tables 9A,9B. The wealth effects are positive with respect to land and non-farm assets, and negative with respect to livestock. No EKC pattern emerges, however, with respect to any asset. Education ceases to have a significant wealth effect, though the substitution effect continues to be negative. Livestock continues to exhibit a positive substitution effect. The net elasticities shown in Table 11B (with respect to different assets at various percentiles of the per capita consumption distribution) are all positive, with the single exception of education. We therefore continue to find evidence contradicting the poverty-environment hypothesis. The evidence regarding the EKC is also weaker: the overall relationship between per capita consumption and collections within villages continues to exhibit an inverted-U pattern (as indicated by Figure 4), but is less pronounced compared with 1995-96. With respect to specific assets, the EKC effects no longer appear for any of them, though education now has a negative impact throughout the distribution.

4 Related Literature

A large body of literature documents the significant reliance of the poor on environmental resources (e.g., see Beck and Nesmith (2001), Angelsen and Wunder (2003) or various studies of Jodha (1986, 1992, 1995)). These typically show that the proportion of consumption accounted by environmental common property resources is higher for the poor compared with non-poor households. This however does not provide evidence in favor of the poverty-environment hypothesis, and is consistent with our finding that the elasticity of firewood collections with respect to various assets is positive but less than one.

Econometric evidence on the relation between income and fuelwood consumption generally provides mixed results. In their survey of micro-studies of the demand functions for firewood, Cooke *et al* (2001) report fuelwood demand income elasticities ranging between -0.31 and 0.06 from various studies over different countries, which suggests that fuelwood is generally an inferior good. However, Cooke *et al* (2001) also note that the income elasticities are not constant across countries and levels of income. More recent studies on Nepal or rural India do not provide support for the energy ladder hypothesis as in most cases: (i) fuelwood is a normal good in those areas (Heltberg *et al* (2000), Gundemida and Kohlin (2003), Adhikari *et al* (2004), Arnold *et al* (2003)); (ii) direct price (or cost of collection) elasticities for firewood are generally negative, but vary a lot, partly as a result of the varying energy needs and availability of substitutes across regions (Hyde and Kohlin (2000), Pitt (1985) and Gundemida and Kohlin (2005)); and (iii) cross-price evidence shows little substitution between fuelwood and other fuels (Cooke *et al* (2001)). Other literature on firewood collection in Nepal stresses the role of non-agricultural 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. This is consistent with our findings comparing Terai and non Terai villages.

Many of these studies however suffer from important weaknesses that we explicitly addressed in this study. They typically ignore censoring, i.e., the fact that some households may not use the resource at all (with the exceptions of Pitt (1985) and Gupta and Kohlin (2003)). Most estimates rely on reduced forms where the inclusion or the omission of explanatory variables is often arbitrary, and not based on an explicit modeling strategy. Some studies rely on market prices for fuelwood, which is inappropriate when transactions are infrequent and most households collect their own firewood.[26] Other studies, based on a non-separable household model, explicitly introduce a measure of the cost of firewood collection, such as collection time or distance to the forest. However, they do not interact these with a measure of income, but rely instead on additive specifications which our model indicates are inappropriate.[27] Additionally, they do not control for village characteristics such as availability of fuel substitutes, infrastructure or climate. Nor do they address the issue of endogeneity of income, or labor supply choices.

Village effects are controlled for in the work of Foster and Rosenzweig (2003) on forest cover estimates in India and Chaudhuri and Pfaff (2004) on household fuel choices in Pakistan. Foster and Rosenzweig find a small (but statistically significant) negative effect in cross-sectional Indian rural household data from 1982. Chaudhuri and Pfaff find strong evidence of a clear transition from traditional to modern fuels as per-capita household expenditure rises in Pakistan (combining rural and urban households). They also find that the use of traditional fuels rises at low levels of income, then remains essentially constant for a wide range of per-capita expenditure levels and falls for high levels of expenditures. The switch to modern fuels in Pakistan identified by Chaudhuri and Pfaff occurs particularly among urban households, where

[26] A difficulty arises because the time to collect is not observed for non-collecting individuals. In this paper, we used the average of collection times reported by collecting households in a village. Another possibility is to predict collection time for non-collectors on the basis of household and village characteristics. We found the results reported here virtually unchanged with this method. Another possibility, followed by Pattanayak *et al* (2004) is to truncate the sample, thereby missing households who do not collect, but this would be subject to a more primary form of censoring bias.

[27] A notable exception is Pattanayak et al (2004) who explicitly incorporate an interaction between collection time and a measure of the wage rate.

fuel substitutes are more easily available than in rural areas. Educational levels in rural Pakistan were substantially above those in Nepal: for instance, 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.[28] It is therefore possible that the results we obtain for Nepal mostly reflect the upward sloping part of an EKC, in the context of villages where firewood is still predominantly collected by the household, and few substitutes are available.

Some authors use remote sensing data to estimate changes in the stock of forest vegetation instead of household individual data (e.g., Foster and Rosenzweig (2003) or Somanathan, Prabhakar and Mehta (2005a, 2005b) for India) . We view our approach as complementary, as it focuses on a flow measure of one major source of human dependence on forests, in contrast to a stock measure of forest vegetation. The advantage of focusing on firewood collections is that it provides a measure of dependence of individual households on the forest, which permits us to directly test the relation between deforestation and living standards at the household level. The disadvantage is that we cannot examine other sources of deforestation, such as commercial felling, government appropriation or conversion of forest to agricultural land. On the other hand, forest vegetation indices are subject to other sources of measurement errors. For instance, satellite images rely on aerial photographs of forest cover, and thus cannot accurately portray degradation in the form of excessive lopping beneath the cover, which our measure incorporates.

[28]Chaudhuri and Pfaff use consumption expenditures directly, while we attempt here to provide results that are less vulnerable to endogeneity biases.

Finally, in Baland et al (2007a), we used an SS specification based on potential income to study analogous issues in the Indian Himalayas. Similar to the results in Table 7, we found there that firewood collections did not significantly vary with potential income. The results of this paper suggest those results may have owed to measurement error and aggregation biases inherent in the SS approach.

5 Concluding Comments

The main finding of this paper is that poorer households in rural Nepal collect significantly less firewood than wealthier households in the same village, contrary to the central premise of the poverty-environment hypothesis. EKC-like inverted-U patterns arose only with respect to education and non-farm business assets, and that too only at the top end of the distribution of per capita household consumption. These owe to strong wealth effects which outweigh associated effects on the shadow cost of time. These possibly reflect the high levels of poverty in rural Nepal, and the lack of availability of modern fuel substitutes.

The other contribution of the paper is methodological. Apart from controlling for village effects, non-linearities and endogenous censoring, we based our estimations on an explicit theoretical model of joint decisions concerning production, employment and fuel collection, in a context where incomes, consumption and firewood costs are endogenous. We also allowed for different assets to exert differential wealth and substitution effects. Using information on assets rather than income or consumption to measure wealth also reduces measurement errors. The difference between the semi-structural and reduced form estimates indicates the severity of these endogeneity, aggregation and measurement problems. Understanding the effects of growth or poverty reduction on the environment thus needs to focus on the source of such changes, in particular on underlying changes in the vector of household assets (which represent changes in occupational structure and education).

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 at a point of time, whose relevance to understanding shifts over time is difficult to assess. The use of longitudinal household data over time would be a big step forward.

This paper focused on household firewood collection, one of many possible causes of forest degradation (apart from timber felling, or conversion of forest into agricultural or pasture land).[29] The data available in the Nepal LSMS do not permit analysis of timber extraction or encroachment. In a set of household and forest surveys in the neighbouring Indian Himalayan region, timber use and encroachment were found to be much less severe causes of forest degradation, compared with firewood collection by neighboring residents (Baland et al (2008)).

The Nepal LSMS data is poor with respect to information concerning prices and avail-

[29] There is a debate as to whether fuelwood lopping efforts have progressed well beyond threshold levels of sustainable use. The fear that future uses worldwide substantially exceed the forests regeneration capacities prompted international donors to launch massive replantation programs (see e.g. Eckholm (1984), FAO (1981)). More recently, the idea of an increasing 'gap' between projected needs and supplies has been questioned, as the early projections grossly under-estimated the forest stocks as well as of the amounts of firewood from outside the forests (see Arnold *et al* (2003: 5)).

ability of fuel substitutes and complements to firewood. 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. Our parallel study in the Indian Himalayas (Baland et al, 2007a and 2008) suggests that the availability of a reliable and cheap substitute, such as subsidized LPG, could reduce firewood collections by a very significant amount, and counter the adverse impact of income growth in the long run.

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