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

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Abstract

We investigate the determinants of firewood collection by rural households in Nepal, focusing on the connection between poverty and forest degradation. Most households collect their own firewood, so we distinguish between the direct wealth effects of increased assets owned from induced effects on shadow cost of time spent collecting firewood. We find that the net effect is negative, as the cost effect dominates. But it is quantitatively negligible: an increase in 10% in income leads to a net fall of 0.2% in firewood collected. Moreover, we find the impact of forest degradation (via increased collection times) on local living standards is also very small. Our results are similar those for the adjoining mid-Himalayan region in India, and imply that demographic changes rather than economic growth will be key in determining the future evolution of forests in this region.

Keywords: Environment, Poverty, Deforestation.

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1 Introduction

Forest degradation in the Nepalese Himalayas is alarming. Between 1947 and 1980, Nepal's forest cover declined from 57% to 23% of the national territory (Myers (1986)), then at an annual rate of 1.8% per year between 1980-2000 (UNEP (2001), FRA (2000)). The current evolution is partly irreversible, as fertile topsoil is being washed out by soil erosion in deforested areas. Deforestation and forest degradation has immediate consequences for the local population in terms of increased fuel scarcity, reduced supply of fodder and leaf-litter manure. As shown in our companion paper on the Indian Himalayas (Baland et al, 2007b), the time needed to collect firewood has increased 60% over the past quarter century, while collections per household have decreased by 40%. Increased scarcity may also affect agricultural operations by reducing the time available for other farm activities: e.g., Cooke (1998) estimated that households in Nepal in 1982/3 spent on average eight hours per day 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 the underlying causes of forest change in Nepal is a first-order priority for research.

A leading hypothesis about the economic determinants of environmental degradation is that underlying poverty is the root cause. 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.[1] According to this view, 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 the environment (e.g., Barbier (1997b), Grossman and Krueger (1995) or Yandle, Vijayaraghavan and Bhattarai (2002)). This hypothesis implies that the effects of economic development and poverty reduction are non-monotonic: rising living standards initially worsen environmental problems, and later improve them. In poor countries, they predict (in contrast to the PEH) that reducing poverty will further worsen environmental problems.

The 'energy ladder' model reflects the PEH hypothesis in the context of forest degradation and firewood use. It predicts that higher incomes induce households to switch away from traditional fuels, such as cowdung and firewood, to higher quality but more expensive substitutes (Arnold *et al* (2003)). The theoretical assumption underlying the energy ladder model is that low living standards induce greater dependence on forest firewood owing to a combination of income and substitution effects. Poor households rely more on forest firewood *vis-a-vis* modern fuel substitutes purchased from the market, because the impact of the lower shadow cost of their time (the chief cost of collecting forest wood) dominates income effects (which may be positive, as higher food expenditures associated with higher income raise demand for cooking energy). This argument is *a fortiori* true if the income effect is negative. Firewood can indeed be considered as an inferior and more polluting energy source, and the sign of the income effect is therefore not entirely clear. Note that the argument concerning the strength of the substitution

[1] 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).

effect is based on an implicit assumption that affordable fuel substitutes exist. If they are not, and income effects are positive, the net effect of reduced poverty could go the other way: the poor may collect less firewood than the rich.

Different views in the literature concerning the economic determinants of environmental degradation can therefore be interpreted as arising from differing presumptions concerning the direction and magnitude of income and substitution effects. Those expressing the view that economic growth will worsen the environment in poor countries (following the EKC literature) are focusing primarily on positive income effects arising out of rising energy demands. 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 income effects may be negative. Given that the net effect is theoretically ambiguous, one needs careful empirical analysis to estimate the income and substitution effects. From this perspective, gross correlations and simple reduced forms are only partially informative. One needs to to understand and estimate the specific channels by which living standards and firewood collections are related, if appropriate policies are to be formulated (Cooke *et al* (2001), Arnold *et al* (2003)).

In this paper, we analyze the economic and demographic determinants of firewood collection on the basis of household level evidence in rural Nepal from the 1995-96 World Bank Living Standards Measurement Survey (LSMS). We focus on firewood collection as a significant cause of forest degradation, while admitting that it is one of many possible causes (which include timber felling, and conversion of forest into agricultural or pasture land).[2] For in-

[2]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)).

stance in a companion paper (Baland et al (2007b)) where we have studied the neighbouring Indian Himalayan forests, encroachment and deforestation are much less severe than forest degradation due to firewood collection by neighboring residents. These result in excessive lopping, meagre canopy cover and weak regeneration rates, while the biomass and the stock of trees often look satisfactory (e.g., in aerial satellite images).[3]

As we discuss in section 4, there are very few rigorous micro-econometric studies on the determinants of fuelwood demand at the household level, with a few recent exceptions (e.g., Chaudhuri and Pfaff (2004), Foster and Rosenzweig (2003)). Contrary to most existing literature, we provide a framework that enables us to estimate separately the income and the substitution effects. The task however is particularly complex as there are no reliable longitudinal data allowing us to answer these questions, forcing us to rely on cross-sectional data. In the approach proposed here, we explicitly address a number of methodological problems.

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 bias the estimates of 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 in-

[3] Specifically, firewood is collected by lopping branches of trees such as oaks in the Terai region and predominantly coniferous species in the non-Terai mountainous belt. Excessive lopping especially of wet, green branches have adverse effects on the growth potentials of existing trees, their resistance to natural calamities, and the regeneration capacity of the forest stock. Lopping starts at the lowest branches and proceeds upwards, so that severely lopped 'pole-stage' trees in this region, standing tall with only the top crown of branches and a naked trunk below, are very common. An ailing forest subject to intensive and fairly regular firewood pressures of this nature can degenerate beyond recovery particularly since hardwood species take nearly 80 years to attain full growth while coniferous varieties require in alpine terrains require nearly 120-130 years to regenerate fully.

struments for income and consumption that do not affect firewood collections are rarely available. We address these problems by using a measure of living standards based on underlying household assets (land, livestock, household size, education etc.) that may reasonably be considered given in the short run, and subject to less measurement error than income or consumption. We develop a model of household decision-making concerning labor supply, fuel choice and consumption for a given composition of assets owned, and use this to derive the empirical specification. This represents the most important difference from earlier versions of this paper, which used consumption as a measure of living standards.[4]

We use the household model to derive a single scalar aggregate of assets (which we call 'potential income') owned by the household to estimate wealth. For this purpose we estimate a household production function, following the approach of Jacoby (1993) to overcome problems with endogeneity of labor supply. 'Potential income' is defined as the income that the household can earn with its assets, if all the labor time available in the household (excluding members who are permanently employed elsewhere) is allocated to self-employment activities. Our results turn out to be robust with respect to use of alternative measures of household living standards.

The second problem concerns measurement of cost of firewood, given the lack of firewood markets. Very few households in our sample purchase firewood, and sales of firewood are equally rare.[5] This implies that the cost of firewood cannot be separated from other household characteristics and

[4]In addition, previous versions of this paper suffered from data errors in measuring consumption. Specifically, the LSMS is characterized by absence of data on consumption for a significant fraction of households, and we inadvertently replaces these missing values of consumption with zeroes. The simple Engel curves as well as regressions reported in the previous version were therefore seriously biased.

[5]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).

decisions. We use our household model to estimate the shadow cost of time for each household, and use this to weight collection times to measure the effective cost of firewood.[6]

Using potential income as a measure of living standards allows us to remove one source of endogeneity bias in estimating the relationship between living standards and firewood collection. There may be many other omitted variables jointly correlated with both variables that may contribute to a spurious relationship. For instance, geography or climate variations may affect both firewood availability and living standards. We control for village-specific characteristics with village fixed effects, examining how intra-village variations in potential income correlated with firewood collection. We control for various other household characteristics available in the LSMS data, such as household demographics and health.

Finally, 18% of households do not collect any firewood at all. This necessitates controlling for endogenous censoring, which created a number of econometric complications owing to the simultaneous control for village fixed effects. For this purpose we use the semiparametric Least Absolute Deviation (LAD) estimator proposed by Honore (1992) for panel regressions with censoring. We find our results are robust with respect to controlling for censoring bias.

Our main results are the following. We obtain very weak support in favor of the energy ladder model. While the income effect is generally positive, the substitution effect is clearly negative, but both are very small in magnitude. Consequently firewood collections are almost insensitive to variations in potential income: the elasticity of collections to changes in income is below 0.01. The impact of living standards on firewood collection is therefore negligible: there is no evidence in favor of the PEH or EKC. Likewise, asset ownership, household size and collection time have a very limited impact on collections. There is remarkably little variation in collections across households with wide disparities in living standards.

[6] For related exercises, see Amacher *et al* (1996) or Hyde and Kolin (2000)).

The low sensitivity of firewood collection to economic determinants may be explained by the fact that, in contrast with Pakistan (Chaudhuri and Pfaff (2004)) or Indonesia (Pitt (1985)), Nepalese households do not use substitutes to firewood, apart from cowdung, leaves and crop residue. First, the greater need for heat in the winter season, particularly in the non-Terai, makes firewood a very effective source of fuel compared to available alternatives. Second, a low population density, combined with the montaineous nature of the area, seriously handicaps the availability of alternative source of fuel in large quantities.

These results suggest that economic growth or reductions in poverty in the Nepalese Himalayas will have negligible effects on the pressure on forests resulting from induced changes in firewood collection. Instead, demographic changes will have a significant impact: collections at the village level will relate proportionally to the number of households residing in the village. Hence migration and fertility patterns are likely to be far more important than living standards. Our results also show that occupational changes and education that raise the shadow cost of time are likely to relieve the pressure on the forests.

We subsequently use our estimates to calculate the reciprocal impact on living standards of an increase in collection times by one hour per bundle, corresponding to a 20% increase over current collection times. We find this effect to also be extremely small, of the order of less than 1% of consumption or potential income for all households. This may help explain why local villagers do not engage in forms of collective action to protect the forests. It also implies that local collection externalities are not large enough to justify policy interventions, which must be based on ecological or non-local spillover effects.

It is also notable that virtually identical results are obtained here as in the neighboring mid-Himalayan region in India (Baland et al (2007)), despite the fact that Nepal is a different country altogether.

The plan of the paper is as follows. Section 2 of the paper provides the theoretical framework underlying our specification of the demand for firewood. Section 3 presents the empirical results. Section 4 discusses the related literature, while Section 5 concludes.

2 Theory

In this section, we present the model underlying our estimation strategy. Consider the total amount of cooking and heating energy used by household i in village v, H_{iv}. Energy can be produced from two sources: firewood and gas (which stands here for all energy sources are sold on the market). Letting G_{iv} stand for the total amount of gas consumed in the household, F_{iv}, for the amount of firewood per capita and n_{iv}, for the number of members in the household, we have:

$$H_{iv} = \theta_g G_{iv} + \theta_f n_{iv} F_{iv}, \tag{1}$$

so that $\frac{\theta_f}{\theta_g}$ represents the gas energy equivalent of one unit of firewood, i. e. the rate of subsitution between gas and firewood. The utility function of a representative member of household i in village v is given as follows:

$$U_{iv} = U(H_{iv}, C_{iv}, l_{iv}, S_{iv}(n_{iv}F_{iv}), a_v) \tag{2}$$

where C_{iv} denotes per capita expenditures on all other goods consumed, l_{iv}, per capita leisure time (including time devoted to domestic tasks), $S_{iv}(n_{iv}F_{iv})$, the total amount of smoke produced by the use of firewood in the household, and a_v stands for the relevant village characterisics, such as village climate and infrastructure. The inclusion of the total amount of energy in the utility function reflects the fact that the energy used for heating and cooking is to a large extent a public good within the household (and smoke a public bad) while consumption expenditures or leisure are not.

Household income is the sum of fixed income (pensions, salaries of permanently employed members and wage employment earnings), denoted P_{iv}, and self employment income, Y_{iv}. The latter is in turn determined by the value of household production, given by a Cobb-Douglas production function of household labour hours, L_{iv}, the productive assets owned by the household: land, A_{iv}, livestock, Ls_{iv}, education, E_{iv} and non-farm business assets, B_{iv}; and village level variables, b_v:

$$Y_{iv} = e^{b_v} L_{iv}^{\alpha_1} A_{iv}^{\alpha_2} Ls_{iv}^{\alpha_3} E_{iv}^{\alpha_4} B_{iv}^{\alpha_5} \tag{3}$$

Let us define N_{iv} as the household labour stock available for self-employment activities. It is obtained by multiplying by 16 hours per day the number of adults (plus an adult equivalent scale of 0.25 for children) that are available for household activities, productive self-employment and forest collection. We can then define the household potential income, W_{iv}, as the self-employment income that the household would earn if it were to fully utilize its labor stock . It is given by:

$$W_{iv} = e^{b_v} N_{iv}^{\alpha_1} A_{iv}^{\alpha_2} Ls_{iv}^{\alpha_3} E_{iv}^{\alpha_4} B_{iv}^{\alpha_5} = \frac{N_{iv}^{\alpha_1}}{L_{iv}^{\alpha_1}} Y_{iv}. \tag{4}$$

which, by construction, always exceeds the actual self-employment income.

Owing to data limitations we will ignore the possibility of firewood markets within the village. 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 therefore assume that firewood used must be entirely collected by the household itself. The cost of using firewood corresponds to the opportunity cost of time involved in collecting it.[7] Since ownership of different assets affect allocation of household time between different occupations, some of which are complementary with firewood collection while others are substitutes, the time taken to collect firewood, t_{iv}^f, also depends on the assets owned by the household. As occupational choices are endogenously determined by labour allocation decisions within the household, we use as proxies the corresponding assets

[7]Note that there is no need to control for the stock of fuelwood available in the village, as the impact of these on fuelwood decisions are fully captured by the collection time (for a similar approach, see also Dewees (1989) and Cooke *et al* (2001)).

owned by the household that influence occupational choices. Letting t_v^c represent the time taken to collect firewood for a household with no assets in village v, we assume:

$$t_{iv}^f = t_v^c(1 + \gamma_1 A_{iv} + \gamma_2 Ls_{iv} + \gamma_3 E_{iv} + \gamma_4 B_{iv}) \tag{5}$$

where γ_i measures the degree of complementarity between the activity associated with asset i and firewood collection. For instance, it might be hypothesized that grazing livestock reduces the time taken to collect firewood ($\gamma_2 < 0$) while running a non farm business increases it ($\gamma_4 > 0$). Finally, the labour allocation constraint is given by:

$$N_{iv} = L_{iv} + n_{iv} t_{iv}^f F_{iv} + n_{iv} l_{iv} \tag{6}$$

Letting $p_{G,v}$ represent the price of gas in village v, the budget constraint can be written as:

$$n_{iv} C_{iv} + p_{G,v} G_{iv} = P_{iv} + Y_{iv}. \tag{7}$$

Using equation (4), it becomes:

$$n_{iv} C_{iv} + p_{G,v} G_{iv} = P_{iv} + \frac{L_{iv}^{\alpha_1}}{N_{iv}^{\alpha_1}} W_{iv}, \tag{8}$$

and, using (6):

$$n_{iv} C_{iv} + p_{G,v} G_{iv} = P_{iv} + \left(1 - \frac{n_{iv} t_{iv}^f F_{iv}}{N_{iv}} - \frac{n_{iv} l_{iv}}{N_{iv}}\right)^{\alpha_1} W_{iv}. \tag{9}$$

The household maximizes (2) by choosing gas, firewood, leisure and consumption expenditures under the budget constraint (9), taking assets, fixed income, demographics and the time taken to collect firewood as given in the short run. This yields the following first-order condition for gas, which takes into account the non-negativity constraint :

$$G_{iv}(U'_{iv,1}\theta_g - \mu p_{G,v}) = 0. \tag{10}$$

For firewood, we have:

$$F_{iv}(U'_{iv,1}\theta_f n_{iv}+U'_{iv,4}S'_{iv}n_{iv}-\mu\alpha_1\left(1-\frac{n_{iv}t^f_{iv}F_{iv}}{N_{iv}}-\frac{n_{iv}l_{iv}}{N_{iv}}\right)^{\alpha_1-1}n_{iv}t^f_{iv}\frac{W_{iv}}{N_{iv}})=0, \tag{11}$$

which can be re-written as:

$$F_{iv}(U'_{iv,1}\theta_f+U'_{iv,4}S'_{iv}-\mu\alpha_1\left(1-\frac{n_{iv}t^f_{iv}F_{iv}}{N_{iv}}-\frac{n_{iv}l_{iv}}{N_{iv}}\right)^{\alpha_1-1}t^f_{iv}\frac{W_{iv}}{N_{iv}})=0, \tag{12}$$

The first order condition for consumption expenditures and for leisure (assuming interior solutions) are:

$$U'_{iv,2}-\mu=0, \tag{13}$$

and

$$U'_{iv,3}-\mu\alpha_1\left(1-\frac{n_{iv}t^f_{iv}F_{iv}}{N_{iv}}-\frac{n_{iv}l_{iv}}{N_{iv}}\right)^{\alpha_1-1}n_{iv}\frac{W_{iv}}{N_{iv}}=0. \tag{14}$$

These four first-order conditions, together with the budget constraint (9), implicitly define the demand functions, which can be written as function of potential income W_{iv}, fixed income P_{iv}, the cost of firewood (equal to the time required to collect one bundle of firewood multiplied by the shadow value of time w_{iv}), household demographics (represented by household size n_{iv} in adult equivalent consumption units) and the price of gas (which is omitted in what follows as, being given at the village level, it is absorbed by the village fixed effect). The shadow value of time, w_{iv}, corresponds to the marginal productivity of labour in self-employment occupations (determined in turn by the labour supply choice and household assets) and is equal to:

$$w_{iv}=\alpha_1\left(1-\frac{n_{iv}t^f_{iv}F_{iv}}{N_{iv}}-\frac{n_{iv}l_{iv}}{N_{iv}}\right)^{\alpha_1-1}\frac{W_{iv}}{N_{iv}} \tag{15}$$

Taking a Taylor expansion, allowing for higher order terms in income and demographics, we obtain the following equation for firewood per capita within the household $f_{iv} \equiv \frac{F_{iv}}{n_{iv}}$:

$$F_{iv} = \beta_0 + \beta_1 W_{iv} + \beta_2 W_{iv}^2 + \beta_3 P_{iv} + \beta_4 w_{iv} t_{iv}^f + \beta_5 n_{iv} + \beta_6 (1/n_{iv}) + \beta_7 a_v + \varepsilon_{iv}]. \tag{16}$$

Finally, to allow for censoring, we estimate the truncated version of (16).

This formulation invites a number of remarks.[8] First, potential income as defined above provides a single measure of wealth which values and aggregates the different assets owned by the household. The main benefit of using potential income is that it is independent of short run labour allocation choices made by the household. It aggregates the assets of the households into a single measure of wealth. Estimations based on reported income rather than potential income are subject to an endogeneity bias, as labour used in self-employment is a decision variable. For instance, it is likely that more dynamic or better skilled farmers will simultaneously choose to work more and to collect more firewood. Our measure of potential income is not subject to this type of bias. Moreover, this measure also removes sources of transitory shocks and measurement error in reported self-employed income. By contrast, fixed income can be considered exogenous in the short run, given the low development of labour markets in the area.[9] In equation (16), the second and third terms on the right-hand side represent the wealth effect on firewood demand. This wealth effect can be positive or negative, as it will include on the one hand rising demand for household energy, and a rising concern with indoor smoke on the other that may tend to reduce demand for firewood and switch to available substitutes. The fourth term is estimated separately from self-employment income as fixed income represents a much

[8]Note that the household size appears in the equation with a linear and an inverse term. Identical results are obtained if a linear and quadratic terms yield are used instead. The use of an inverse here allows us a direct comparison to the results obtained for India in Baland et al (2007a) where the specification is based on a linear expenditure system which yields an inverse term in household size.

[9]We introduce fixed income separately from self-employment income as it represents a much more regular and certain source of income, which may affect the demand for a substitute such as LPG. This is a more general model than the one in which one parameter is estimated for income defined as the sum of the two types of income.

more regular and certain source of income, which may affect the demand for a substitute such as gas. This is a more general model than the one in which one parameter is estimated for income defined as the sum of the two types of income. (The coefficients estimated turn out to be surprisingly similar however.)

Second, the shadow value of time w_{iv} increases with potential income W_{iv} because the marginal productivity of self-employed labour is an increasing function of the assets owned by the household that are complementary to labour supply. Wealthier households have a higher value of time, and a higher shadow price of using firewood. This implies that the substitution effects also rise with W_{iv}. To the extent that the wealth effects are positive, and the substitution effects are negative, a rise in wealth of the household will tend to raise both at the same time, so the overall effect is theoretically indeterminate.

Third, if labour markets were perfect, the valuation of household time would simply be the market wage rate. Here however, the shadow value of time is the marginal productivity of household time, estimated using the household production function.[10] One problem with using the measured shadow wage as a determinant of the shadow price of firewood is that it depends on endogenous labour supply decisions of the household. From (15), per capita potential income is a major determinant of the shadow value of time. Therefore, we shall use W_{iv}/N_{iv} as a proxy for the shadow wage rate w_{iv}. (As we show in Figure 1 below, the two co-move closely.) Recalling the

[10] One source of imperfection is the existence of nonpecuniary costs for family members, especially women and children, to work outside the home or own farm. Another source of divergence between (measured) 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 demand periods) turned out to be substantially above shadow wages (which pertain to year-round labour). Hence wage employment earnings were intramarginal, and the margin of labour-leisure choices operated solely with respect to home production.

formulation of collection time t_{iv}^f above as a function of household assets, the firewood demand equation can now be entirely written as a function of fixed household characteristics as follows:

$$\begin{aligned} f_{iv} &= \max[0, \beta_0 + \beta_1 W_{iv} + \beta_2 W_{iv}^2 + \beta_3 P_{iv} + \beta_4 \frac{W_{iv}}{N_{iv}} t_v^c (1 + \gamma_1 A_{iv} + \gamma_2 Ls_{iv} \\ &\quad + \gamma_3 E_{iv} + \gamma_4 B_{iv}) + \beta_5 n_{iv} + \beta_6 1/n_{iv} + \beta_7 a_v + \varepsilon_{iv}] \end{aligned} \qquad (17)$$

The substitution effects are now identified (separately from the income effect) by the interactions between per capita potential income (W_{iv}/N_{iv}) of the household, average collection time in the village (proxied by t_v^c) and assets owned by the household.

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. This survey covered 274 wards (villages) in the rural area. We focus only on villages in the rural area as it is there that firewood collection is more likely to be important than in urban areas. Additionally, it is not clear that the specification of the demand function should be identical across the two areas: in towns, markets are more active, fuel substitutes more easily available and self-employment is less frequent. We therefore use only the data for the 2222 households in 204 rural villages, once households and villages with incomplete or missing data are dropped.

Table 1 shows that wood fuel is the main source of energy for cooking and heating for 83.4% of the households (the other leading sources being cowdung (9.5%) and leaves or straw (3.1%)). Only 4.1% of the households use kerosene or gas as the primary source of cooking or heating fuel.

Table 2 indicates that, on average, a household collects 18.3 bharis (i.e., a headload) or bundles of firewood per capita per year, while 18% of the sample does not collect firewood at all. 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 is 1.56, of which female adults account for 0.94).[11] From Table 3, 73% of the collecting households collect firewood from a government or community forest, with the remaining households collecting either from their own lands or other sources (such as from roadsides).[12] The average time reported to collect one bundle of firewood is 5.01 hours. The government of Nepal introduced a community forestry scheme in 1993, handing over forest areas to be managed by local communities.[13] In our sample, 9% of the households on average report collecting from a community forest; 34% 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.

[11] Cooke (1998) and Adhikari (2002) similarly find a high involvement of the spouse and the children in collecting firewood in Nepalese households.

[12] 59% of all households are collecting from state and community forests, and 18.1% of them are not collecting at all (Table 3).

[13] 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. 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.

The mean annual consumption for a household is Rs. 37095.[14] Given that the average household size is 5.16 (in adult equivalent units with members of age below 16 being counted as half an adult), the corresponding annual per capita consumption is approximately $225 (in 1995-96 prices). The proportion of households with consumption levels below 1$ per day per capita reaches 90%, indicating very high levels of poverty. The majority are engaged in self-employed agricultural activities and livestock rearing. Principal assets consisted of cultivated land, livestock and nonfarm business assets.[15] Education levels are low: in 50% of the households, no adult has any education. On average, 7% of household members suffer from some form of chronic illness.

The villages vary considerably with regard to elevation, which ranges 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, has experienced the greatest deforestation since the 1950s. Table 2 also shows the principal characteristics of the Terai and the non-Terai households in the LSMS sample. Approximately 72% of the households in the sample are from the non-Terai region. The two regions do not differ significantly with respect to average consumption and household size. Households in the Terai region have less livestock, cultivate more land, are more educated and allocate a larger fraction of household employment in the non farm sector. 94% of the households in the non-Terai region collect firewood, and 52% in the Terai. The former also collect 39% more firewood than the latter. The average collection times are approximately the same in both regions, but fuel needs differ a lot between the two regions: the Terai benefits from a sub-tropical climate, with an average temperature well above $20°C$ (and above $15°C$ year round), while

[14]It is important to emphasize here that consumption data provided in the LSMS were often incomplete. Given that our main estimation results are given in potential income, consumption data are used only as a descriptive measure. Of the 2222 households with complete observations on potential income only 1387 households have data on consumption.

[15]Only big livestock is considered as small livestock (goats and sheep) turned out to be insignificant in all specifications.

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 also provide separate estimates f or the two regions.

3.2 Simple Engel Curves

The first step in the empirical analysis is estimation of the household production function, equation (2). Table 4 shows the estimates obtained with village fixed effects and labor hours instrumented by household demographics (following Jacoby (1993)).[16] The elasticity with respect to labor hours is 0.39, indicating that the shadow wage, defined as the marginal productivity of labour, is 39% the size of self-employment earnings per hour (average product). Household income is particularly sensitive to ownership of land, with an elasticity of 0.43. The elasticity with respect to non-farm business assets is 0.09, and to livestock is 0.28. The elasticity with respect to schooling of adults is statistically insignificant, which could reflect a tendency for more educated households to be engaged in salaried employment.

The estimated production function is used to calculate the shadow wage and potential income. As explained above, potential income is estimated by replacing the actual amount of labour worked in the household by the total amount of labour available for self-employment in the household. The shadow wage, which is defined as the marginal productivity of labour in self-employment occupations, depends on labour supply decisions and is thus endogenously determined. Table 5 presents the estimated values of potential income and shadow wage for all households. The average per-capita potential income is Rs 29223.89 per year but varies a lot across households. The average shadow wage is equal to Rs 11.55 per hour.

[16]We use reported family labor hours in self-employed occupations, applying a weight of 0.25 to child labor hours. For instruments we use number of adult men, women, old men and old women that are not engaged in permanent employment. We do not include the number of children among the instruments, since fertility decisions may be correlated with unmeasured household attributes relevant to its productivity.

In table 5, we provide more details on these variables: the median potential income is equal to Rs 8648.45 per person per year, and varies from Rs 4925.91 at the first quartile to Rs 16646.62 at the third quartile. The mean is Rs 29223.89, which exceeds the third quartile. The high value of the mean and standard error of potential income reported in Table 2 are caused by some large values at the top end of the distribution. A similar phenonenon is observed for the shadow wage, with the first, second and third quartile (in rupees per hour) of 1.46, 2.76 and 5.67 respectively. A Gaussian kernel regression between potential income and shadow wage is shown in Figure 1: the relationship is increasing, and approximately linear. This further justifies the use of potential income as a measure of the opportunity cost of time in the firewood regression.

The distribution of consumption expenditures per capita is consistent with that of potential income per capita, but is less dispersed. This is expected, as poorer households typically adjust to their lower asset base by working more and saving less. Figure 2 shows the non-parametric relationship between per capita potential income and per capita consumption levels: the relationship is also increasing. Figure 3 presents a non-parametric relationship between per capita firewood collection and per capita potential income. The relationship between the two is initially rising and then falling, a typical EKC pattern. However, the overall variation in firewood collections is small: a change in per capita potential income from the first to the third quartile is associated with a change from 17.6 to 19.1 bundles collected per capita.

Table 6 presents results obtained from regressing per capita firewood collection on potential income and its square in columns 6.1 and 6.2. The specifications used exclude productive assets, education or demographics, and therefore correspond to simple Engel curves. The first estimation uses simple OLS, which is subject to a number of econometric problems (which also plague Figure 3). Unobserved village variables such as the size of the forest stock, collection time, climate, urbanization or access to fuel substitutes can jointly affect potential income and collection activities. One solution is to use village fixed effects that control for unobserved village attributes. The second problem arises from censoring, since 18% of the households do not collect at all. The censoring introduces nonlinearity in our 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, for the estimation reported in 6.2, we use the semiparametric estimator proposed by Honore (1992) for censored data with fixed effects. This estimator will be used in the estimations reported in all subsequent tables. In columns (6.3) and (6.4), we report the estimated coefficients obtained when using consumption expenditures as a measure of living standards. These suffer from biases owing to endogeneity of consumption: omitted household characteristics such as industriousness, location or illness could affect both consumption and collections.

In all columns, the estimated coefficients display a negative relationship between income and collections over the entire range, with a tendency for the slope to flatten at the very top. This is consistent with the PEH. However, the magnitude of the effects are weak and small: column 6.2 implies a 10% increase in potential income of all households is associated with a statistically significant fall in collections of -0.03 bharis per capita. Given an average collection of 18.3 bharis per year, this corresponds to an elasticity of -1.6%, which is quantitatively negligible. The magnitude of the effect is similar if one uses consumption expenditures as a measure of living standards.

3.3 Firewood Collection: Detailed Results

We now add controls that allow income and substitution effects to be separated, and effects of asset composition on the shadow cost of time to be estimated. Column 7.1 in Table 7 presents the estimated regression of per capita collections, based on (equation (17)). In column 7.2, we include a control for the fraction of household members who are chronically ill, since this may affect both their labor supply and ability to collect firewood. The effect of occupational structure on collections is further explored in regression 7.3 which replaces the interactions of collection time with different assets and the opportunity cost of time by its interaction solely with the fraction of household working hours in non-farm occupations. In 7.4, the opportunity cost of time is measured by the marginal productivity of labour. Regression 7.5 shows the results obtained when consumption expenditure is used to measure living standards, and per capita expenditure is used to measure the opportunity cost of time. In Table 8, we show the net impact on per capita collection of a 10% increase in the relevant variables for each household, using their direct (as estimated in 7.1) as well as their indirect effects through the potential income equation (Table 4). The 10% increase in productivity is of particular interest, as it corresponds to a 10% increase in (potential) income which is independent of changes in asset composition or labor stock.

The evidence does not offer much support in favor of the energy ladder model: firewood collections hardly vary with income. A 10% increase in productivity causes a net fall in firewood collection of -0.036 bharis per capita per year, which corresponds approximately to a fall of 0.2%, i.e., an elasticity of -0.02. So the results do not vary much with the choice of measure of living standards.

The inelasticity of firewood collection is consistent with numerous studies in Asia and Africa documenting that the ratio of common property resource use to consumption is highest among the poor (e.g., Beck and Nesmith (2001), Angelsen and Wunder (2003)). A constant level of collection across households with widely varying income would imply that the ratio of collection to income is decreasing in the latter.

The results presented in Table 7 separate the effect of rising assets into income and cost-of-collection effects. The income effect is positive, very small and insignificant. Irrespective of how consumption is measured, there is no evidence in favor of the hypothesis that firewood is an inferior good. An important reason for the low income effect could be the restricted use of modern fuel substitutes shown in Table 1, owing to restricted access or high cost of these. In contrast to the income effect, the cost of collection effects are statistically significant and negative: higher incomes raise the shadow cost of collection time which reduces firewood collections. However, they are quantitatively small in magnitude.

The interaction of collection time with household assets supports the hypothesis that livestock grazing and firewood collection are complementary activities: the coefficient estimated is consistently positive and significant. In contrast, land, education and non farm business assets all tend to increase collection costs. The effect of occupational structure on collections is further explored in column 7.3 which replaces the interactions of collection time with different assets and the opportunity cost of time by its interaction solely with the fraction of household working hours in non-farm occupations. This is negative and almost significant (the p-value is .12). Hence a greater reliance on non-farm occupations is likely to increase the shadow cost of collection time, presumably since such occupations require household members to work in neighboring urban or semi-urban locations located further away from the forest. The determinants of reliance on non-farm occupations are presented in Table 10. Larger households with less land, less livestock and whose parents were not farmers tend to be more involved in non-farm occupations.

A 10% increase in collection time is associated with a fall in collections by only 0.3%. This suggests that forest degradation and related increases in collection times will do little to moderate collections and provide an automatic self-correcting process when a degradation process is under way.

Per capita collections decrease with household size. An increase in household size has two main effects. One is to increase the labour force, and hence the potential income in the family. The other is to affect the demand for firewood. The net effect however is negligible, as shown in Table 8 where a 10% increase in household size reduces per capita collection by barely -0.03 bharis per year (which corresponds to an elasticity of -0.02). Therefore the key demographic determinant of the pressure on a forest is the number of households in neighboring villages, rather than size per household. This suggests that household division will raise the pressure on forests.

To check that the foregoing results are not affected by aggregation of regions differing in climate, economic and ecological characteristics, we re-estimated regression 7.1 separately for Terai and non-Terai households. Due to missing values, the regression sample for Terai and non-Terai shrank to 496 and 1301 observations respectively. The non-Terai region is of particular interest since it corresponds to the hilly and mountainous areas of Nepal, which are the most vulnerable to deforestation. As discussed before, in this region, more than 94% of the households collect firewood, fuelwood markets are almost non-existent, and fuel subsitutes are not easily available. The results are reported in Table 9.

Similar to the pooled data, the estimated relationship with consumption is very weak. The coefficients estimated are very close to those estimated for the pooled model, though generally less significant. Livestock ownership again increases firewood collection through its negative impact on collection times. The role of non-farm business assets is also worth noting here, as their impact on the shadow cost of time is strong and significant.[17] In the high altitude regions, these non-farm business assets partly pertain to the trekking and tourism industry which has accelerated since the 1950s in the Nepalese Himalayas.

Our analysis could be criticized on the grounds that in the longer run, productive assets are endogenous. In particular, omitted variables such as entrepreneurship, dynamism or better business opportunities will all lead to an over-estimation of the impact of these assets on potential income. As a result, the real impact of potential income on firewood collections through both the substitution and the income effects may then be more important (in

[17]Even though we do not report them here, we also ran estimates replacing living standards by various assets, as the latter are also determinants of the former. In this 'reduced form' approach, we found a strong and positive wealth effect associated with the amount of land cultivated.

absolute value) than the one we have estimated. This would further reinforce our results.

In addition, we focused on firewood collected by the household, excluding amounts sold or bought. As discussed in the introduction, such sales are too rare, and we do not have enough information in the LSMS data to integrate them in the analysis. To the extent that firewood is likely to be collected and sold by poorer households and bought by richer ones, the exclusion of such sales further reinforces our central result. Poorer people report more collections than they consume, and the richer ones report less than they consume: hence the measured differences in collection understate differences in consumption.

3.4 Reciprocal Impact of Degradation on Living Standards

A major impact of forest degradation for the villagers is the resulting increase in 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. The question however is the impact of such an increase on the welfare of the villagers. To do this, for a small increase in collection time, we can apply the Envelope Theorem and approximate the cost to the household 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.[18] A household collects on average 18.3 bharis per capita per year. At the average shadow wage of Rs. 6.55 per hour, an increase by one hour in collection time represents an income loss of Rs 119.9

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

per year. Given a per capita yearly consumption expenditures of Rs 8490, this corresponds to a 1.0% drop in consumption, or 0.5% drop in potential income. If the median shadow wage is used instead to value time, these proportionate drops are 0.9% and 0.6% instead. The magnitude of the local externality is thus very small.

The low average impact may, however, conceal large distributional effects. The distribution of the effect is is not *a priori* obvious: poor households have a lower shadow wage, but also lower consumption expenditures and potential income. Keeping an average collection of 18.3 bharis per year, we can compute the proportional income loss for a household in the first decile, by using the shadow wage and consumption expenditures corresponding to this decile. The proportional income loss thus computed is equal to 0.7%. The corresponding figure for the top 90% is equal to 1.1%. The impact of degradation on living standards is thus surprisingly small across the entire range of households. This may explain the lack of concern by villagers about the degradation of village forests. It also suggests that the argument for policy interventions to arrest degradation need to be based on the importance of non-local externalities or ecological effects, such as erosion, biodiversity, landslides and siltation of downstream rivers.

4 Related Literature

A large body of literature documents the significant reliance of the poor on environmental resources (e.g., see the survey by Beck and Nesmith (2001), Angelsen and Wunder (2003) or various studies of Jodha (1986, 1992, 1995)). This however does not speak to how this dependence changes with a rise in consumption, the central concern of this paper. Some studies do show that the proportion of consumption accounted by environmental common property resources is higher for the poor compared with non-poor households. This is perfectly consistent with our estimate of a negative (gross) income elasticity of firewood collections.

An additional drawback of much of the empirical literature concerning common property resources is that it utilizes cross-sectional data at the level of villages or communities, rather than households (e.g., Agrawal and Yadama (1997), Bardhan (2000), Varughese (2000)). As we have argued above, cross-village evidence is potentially biased by omitting unobserved village characteristics which are correlated with both living standards and firewood collection, such as topography, forest conditions or access to markets. Our approach controls for unobserved village characteristics by examining intra-village variation of collection across households, while incorporating the fact that some of them do not collect at all.

The evidence on the relation between income and fuelwood consumption is mixed. 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 might not be constant across countries and levels of income: "Some analyses have observed that fuelwood is a normal good for lower income households but an inferior good for higher income households" (Cooke *et al* (2001:33)). 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), see also 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 (e.g. cow dung or crop residues) 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 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. This is consistent with our findings concerning the impact of nonfarm employment opportunities.

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)). Some of them do not include income or consumption expenditures, and rely on proxies such as landholdings (e.g. Heltberg *et al* (2000)). Most estimates rely on reduced forms where the inclusion or the omission of explanatory variables is often arbitrary, and not based on a careful modelling strategy. Some studies rely on market prices for fuelwood, which is appropriate when an active market exists (as in the Indonesia study by Pitt (1985)), but not when transactions are infrequent and most households collect their own firewood, provided such prices are observable at all.[19] 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. They however do not interact these with a measure of income, but rely instead on additive specifications which, as we argued above, is not appropriate as it provides biased estimates of the income and the substitution effects. (One notable exception is Pattanayak et al (2004) who explicitly incorporate an interaction between collection time and a measure of the wage rate.) Additionally, they do not control for various biases at the village and household levels, which may be partly responsible for the discrepancy between their results and ours. For instance,

[19] 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. This procedure is valid as long as villages are not too dispersed so that all villagers face the same distance to the forests. 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.

the availability of fuel substitutes, better communication infrastructures or a higher average temperatures are village characteristics that are correlated with both lower poverty and lower firewood collections. We control for these unobserved characteristics by the use of a village fixed effect. More importantly, all these studies do not address the issue of the endogeneity of income, or labour supply choices, which is central to our methodology.

An alternative approach followed in the literature (e.g., Foster and Rosenzweig (2003) or Somanathan, Prabhakar and Mehta (2005a, 2005b) for India) uses remote sensing data to estimate changes in the stock of forest vegetation instead of household individual data. We view our approach as complementary, as it focuses on a flow measure of one major source of dependence on forests, in contrast to a stock measure of forest vegetation. The advantage of our approach is that it provides a measure of dependence of individual households on the forest, which permits us to directly test the relation beween 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.

Pitt (1985) estimates demand for alternative fuels using household level data for Indonesia, where fuel markets are relatively well developed.[20] He finds a negative income elasticity for the demand of firewood, but a strong and positive elasiticity for charcoal. He also finds little substitution effects between kerosene and fuelwood, particularly in rural areas, which leads him to question the distributive impact of kerosene subsidies that would disproportionately favor urban households. Note that his analysis is not based on the opportunity cost of collection, but on observed fuelwood prices, in a con-

[20]Unfortunately, very few village controls are used, so that his estimates may suffer from the above-mentioned omitted variable bias.

text where markets for fuelwood, charcoal and kerosene are well-developed. Using somewhat different methodologies, Chaudhuri and Pfaff (2004) and Foster and Rosenzweig (2002) estimate Engel relationships using household level data with village fixed effects, for Pakistan and India respectively. Foster and Rosenzweig find a small (but statistically significant) negative effect in cross-sectional Indian rural household data from 1982, consistent with our results here. 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 is essentially constant for a wide range of per-capita expenditure levels (they however find that, at very low levels of income, fuel use is likely to rise) and falls for high levels of expenditures. The similarity between all these results is striking, all the more so that they arise in different contexts with varying access to alternative fuels, education levels and levels of per capita income. For instance, the switch to modern fuels in Pakistan identified by Chaudhuri and Pfaff occurs particularly among urban households, where fuel substitutes are more easily available than in rural areas. Rural households also used kerosene and electricity in cooking more frequently. Thus, the proportion of rural households using kerosene and electricity as primary source of fuel for cooking in Pakistan was 9%, compared to 4.1% in Nepal.[21] Moreover, Chaudhuri and Pfaff use consumption expenditures directly, while we provide here an attempt to provide results that are less vulnerable to endogeneity biases.

Finally, in Baland et al (2007a), we follow the same approach as in this paper to analyze firewood collection in the Indian Himalayas, based on data we collected ourselves between 2000-2004. The results also show that the income and the substitution effects neutralize each other, so that firewood collections are essentially inelastic with respect to improvements in living

[21] Educational levels in rural Pakistan were substantially above those in Nepal: e.g., the average years of schooling of household heads in the rural Pakistan sample was 6.3 years, in comparison to 1.87 years in the rural Nepal sample.

standards. In particular, we find no evidence for any effects of poverty or growth on forest pressure, nor any Kuznets-curve patterns: the estimated elasticities are surprisingly close to those estimates for Nepal as an increase in 10% in income in India (as measured by asset productivity) causes a net fall in collection by less than 0.1%. We also find a large impact of occupations (livestock grazing) and household size on collections. As the information there is much richer than for Nepal, we were able to estimate the impact of the availability and price of substitutes: a large subsidy on LPG, covering 2/3 of its current price, would lower firewood collections by 44%.

5 Concluding Comments

Our principal findings are the following. First, living standards have a very small and negative impact on firewood collection in Nepal. We decomposed the Engel effect into a wealth effect and a cost of collection effect. The cost of collection is defined as the time taken to collect firewood from the forest valued at the shadow cost of the household's time. To measure the shadow cost of collection time, we proposed the estimation of a self-employment production function which allowed us to compute a measure of the shadow cost which is independent of the household labour supply choices. The wealth effect tends to be generally positive, while the cost of collection effect is clearly negative, with a net effect on collection which is very small: on average, a rise in 10% in living standards implies a fall of 0.2% in firewood collected. A 10% increase in productive assets, such as land or education, causes a change in collection which lies between -0.2% and 1%. Other estimations based on Engel curves or alternative measures of incomes similarly suggest that living standards have a negligible impact on firewood collections. We thus found no support for the Poverty Environment Hypothesis, the environmental Kuznets curve, or the energy ladder model.

Second, firewood collections are not very sensitive to collection costs: an increase in collection time by 10% implies a reduction of 0.3% in collections.

There is therefore no real feedback mechanism from forest degradation on individual collections. This in turn implies that future population increases (i.e. more households in the village) will result in a proportional increase in total collections and pressure on forest resources.

Finally, we showed that the opportunity cost of increased collection time is thus very low, as an increase in collection time by one hour is equivalent to an income loss of about 1%. This helps explain the inelasticity of collections to collection time. In short, demographic changes, rather than economic growth, are going to be key in predicting future pressure on the forests.

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 over time would be a big step forward. Other data limitations concern the absence of information on forest stock and quality: what is the relative importance of firewood collection, conversion to agricultural land, private concessions to timber merchants, and illegal felling in driving deforestation? To assess this question we would need data concerning changes in forest stock over time, for instance from detailed forest surveys, possibly complemented by land satellite images.

The Nepal LSMS data is poor with respect to information concerning prices and availability of fuel substitutes and complements to firewood: the responses contain many missing values which shrink the sample size considerably and were not included in the regressions to avoid possible sample selection biases. Understanding the process by which the extent of substitutability among alternative energy sources is expanded is of crucial policy importance. The process of modernization can conceivably be modified by policies of expanding transport networks, and increasing availability of fuel substitutes. Our parallel study in the Indian Himalayas (Baland et al, 2007 a and b) 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 demographic pressures in the long run.

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TABLE 1: Household Energy Sources						
Energy Source	Wood	Cowdung	Leaves & Crop Residues	Kerosene	Others	Number of obs.
Primary	83.4	9.5	3.1	2.5	1.6	2222
Secondary	15.9	17.8	58.8	5.7	1.8	831
(Percent of Households Reporting)						

TABLE 2: Descriptive Statistics: Household Characteristics

Variable	All rural villages n=2222* Mean (Standard Deviation)	Minimum	Maximum	Number of zeroes	Terai n=496 Mean (SD)	Non-Terai n=1301 Mean (SD)
Per capita wood collection (bharis/year)	18.31 (18.15)	0	144	410	9.12 (13.65)	21.36 (16.26)
Proportion of households not collecting	0.18				0.48	0.06
Annual Cons. Expenditure (Rs) (1387 observations)	37095 (30978)	1654	318444	0	35625 (23883)	34764 (26577)
Livestock (Number of Cows and Buffaloes)* Owned by the household	1.81 (1.13)	0	3	311	1.48 (1.12)	1.99 (1.08)
Amount of land cultivated (Has)	0.60 (1.445)	0	28.30	945	0.74 (1.73)	0.58 (1.44)
Value of Non-Farm Business Assets (Rs)	13363 (121309)	0	3000000	1883	4168 (24029)	6594 (61441)
Total number of years of schooling of all adults in the household (years)	12.51 (16.88)	0	110	1055	14.08 (17.48)	11.86 (16.30)
Fixed income (Rs)	4491 (7581)	0	95312	1030	4836 (7922)	4564 (7529)
Fraction of time used in non-farm occupation	0.31 (1.11)	0	1	1257	0.36 (0.92)	0.27 (1.16)
Potential Income (Rs)	121304 (435118)	369	1.48E+07	0	117191 (345511)	106174 (454365)
Fraction of Household Members with chronic illness	0.068 (0.137)	0	1	1601	0.06 (0.12)	0.08 (0.15)
Household size	5.93 (2.92)	1	29	0	6.49 (3.32)	5.99 (2.62)
Household Size (Adult Equiv.)	5.16 (2.51)	0.5	24	0	5.64 (2.88)	5.20 (2.28)
Shadow wage	11.55 (200.53)	0.024	9404.81	0	15.82 (29.14)	5.18 (4.83)

Note: For the Terai and Non-Terai households, the data reported here are for those villages for which village elevation information was available.

TABLE 3: Descriptive Statistics: Village Characteristics

Variable	All Rural Villages n=204				Terai n=42	Non-Terai n=113
	Mean (Standard Deviation)	Minimum	Maximum	Number of Zeroes	Mean (SD)	Mean (SD)
Fraction of household with per capita consumption less than $1/day	0.90 (0.23)	0	1	0	0.97 (0.09)	0.97 (0.06)
Fraction of Households Reporting Collecting Firewood from a FUG forest	0.09 (0.18)	0	0.92	134	0.02 (0.14)	0.14 (0.34)
Fraction of Households Reporting Collecting Firewood from a state forest	0.50 (0.35)				0.44 (0.50)	0.60 (0.49)
Mean Collection Time in the village (hrs/bhari)	5.01 (2.38)	0.50	12.4	0	4.84 (2.41)	5.23 (2.03)
Elevation above sea level (Feet) (# obs= 155)	3724 (3090)	191	17460	0		

TABLE 4: Household Production Function		
Dependent Variable: Log of Total Income from Self-Employment Activities		
	Coeff.	Standard Error
Log of Labour Hours	0.39***	0.05
Log of Non-Farm Business Assets	0.089***	0.01
Log of Land	0.43***	0.07
Log of Large Livestock	0.28***	0.08
Log of Total Household Education	0.03	0.03
OLS with Village Fixed Effects. Instruments used for Labor Hours are the number of adult men, women, old men and old women.		
*: significant at 10%, **: significant at 5%, ***: significant at 1%		

TABLE 5: Potential Income and Shadow Wages								
	Mean	Standard Deviation	10%	25%	Median	75%	90%	# of obs.
Per Capita Potential Income	29223.89	133193.40	2723.92	4925.91	8648.45	16646.62	45.637.88	2222
Per Capita Consumption Expenditures	8539.82	10683.3	2937.33	4030.16	5950.19	9144.62	14479.44	1385
Shadow wage (Rs/hour)	11.55	200.53	0.83	1.46	2.76	5.67	13.99	2222

TABLE 6: Firewood Collection Engel Curves				
Dependent variable: Per Capita Firewood Collection (#bharis/year)				
	(6.1) OLS	(6.2) LAD	(6.3) OLS	(6.4) LAD
Potential Income	-4.21E-5***	-1.01E-04***		
	(1.01E-5)	(2.22E-05)		
Square of Potential Income	3.11E-11***	7.62E-11***		
	(1.4E-11)	(1.92E-011)		
Consumption Expenditures			-6.31E-05*	-1.5E-4***
			(3.3E-5)	(4.7E-5)
Square of Consumption Expenditures			8.42E-11	3.9E-10
			(1.7E-10)	(2.8E-10)
Village Fixed Effects	No	Yes	No	Yes
Number of Observations	2222	2222	1385	1385
R^2	0.01		0.008	
*: significant at 10%, **: significant at 5%, ***: significant at 1%				
Standard errors in parentheses				

TABLE 7: Firewood Collection Regressions					
Dependent Variable: Firewood Collection per capita (# bharis/year) Trimmed LAD estimates					
	7.1	7.2	7.3	7.4	7.5
	Basic model	with chronic illnesses	with non-farm occupations	with Shadow Wage	with Consumption Expenditures
Potential income	4.59E-06 (2.36E-05)	1.82E-06 (2.39E-05)	2.05E-05 (2.17E-05)	6.78E-06 (1.99E-05)	
(Potential Income)^2	2.25E-11 (2.45E-11)	2.29E-11 (2.42E-11)	-2.36E-11 (2.06E-11)	2.74E-11 (2.52E-11)	
Fixed Income	3.89E-05 (6.53E-05)	4.19E-05 (6.54E-05)	6.63E-05 (6.69E-05)	4.47E-05 (6.33E-05)	
Consumption Exp					1.64E-04** (7.78E-05)
(Consumption Exp.)^2					-7.603E-10 (5.42E-10)
Collection Time* Cost of Time	-2.33E05** (1.74E-06)	-2.22E_05** (1.75E-06)	2.94E-06 (1.64E-05)	-0.13* (0.09)	-1.51E-05 (1.95E-05)
Large Livestock*Collection Time*Cost of Time	1.56E-05*** (5.09E-06)	1.59E-05*** (5.07E-06)		0.041* (0.029)	1.16E-05** (5.07E-05)
Land Owned*Collection Time*Cost of Time	-9.56E-07* (6.702E-07)	-9.61E-07* (6.85E-07)		-5.97E-04 (0.005)	1.19E-06 (9.112E-07)
Adult Education*Collection Time*Cost of Time	-4.55E-07 (4.09E-07)	-4.55E-07* (4.12E-07)		-1.06E-07 (0.0012)	-1.65E-07 (4.24E-07)
Nonfarm Business Assets* Collection Time*Cost of Time	-1.23E-11*** (4.50E-12)	-1.32E-11*** (4.61E-12)		-1.065E-07 (7.22E-08)	-8.05E-12 (1.08E-11)
Non-Farm Occupation* Collection Time			-1.03*** (0.325)		
Household Size (Adult Equiv.)	-0.587** (0.382)	-0.562** (0.386)	-0.804** (0.389)	-0.688** (0.382)	-0.55 (0.397)
1/Household Size (Adult Equiv.)	47.96*** (10.18)	47.79*** (10.10)	43.42*** (10.21)	48.65*** (9.66)	50.98*** (11.34)
Proportion of hh members with chronic illnesses		1.89 (3.94)			
Number of observations	2222	2222	2222	2222	1387

The cost of time used is the per capita potential income for equations (7.1), (7.2) and (7.3), shadow wage for equation (7.4), and per capita consumption expenditures for equation (7.5). The * in the Variable column denotes interactions.

*: significant at 10%, **: significant at 5%, ***: significant at 1%, Standard errors in parentheses

TABLE 8: Estimated Impact on Firewood Collection	
Percentage Change in Per Capita Wood Collection due to a 10% Increase in	
Productivity	-0.036
Non-Farm Business Assets	-0.005
Total Land	-0.02
Cows and Buffaloes	0.083
Total Education	-0.015
Household Size	-0.03
Collection Time	-0.045

TABLE 9: Firewood Regressions, By Region		
Dependent Variable: Firewood Collection per capita (# bharis/year)		
	Terai	non-Terai
Potential Income	9.12E-5 (8.67E-5)	-2.18E-5 (3.96E-5)
Square of Potential Income	-1.92E-10 (3.25E-10)	1.45E-10* (1.10E-10)
Collection Time* Cost of Time	-7.69E-5* (4.53E-5)	3.56E-6 (1.64E-5)
Fixed Income	2.85-5 (9.612E-5)	6.37E-5 (7.45E-5)
Large Livestock*Collection Time*Cost of Time	1.71E-6** (7.84E-6)	1.16E-6 (4.76E-6)
Land Owned*Collection Time*Cost of Time	2.515E-6 (2.69E-6)	-1.96E-6** (8.94E-7)
Adult Education*Collection Time*Cost of Time	-3.07E-7 (4.98E-7)	3.82E-7 (4.11E-7)
Nonfarm Business Assets* Collection Time*Cost of Time	-1.02E-09*** (3.46E-10)	-9.05E-11* (5.49E-11)
Household Size (Adult Equiv.)	-0.69 (1.28)	-1.007* (0.524)
1/Household Size (Adult Equiv.)	81.77** (33.63)	31.80*** (12.09)
Number of observations	496	1301
*: significant at 10%, **: significant at 5%, ***: significant at 1%.		

TABLE 10: Determinants of Non-Farm Employment	
Dependent Variable: Fraction of Household Working Hours Allocated to Nonfarm Employment	
Total Land	-0.017* (0.013)
Nonfarm Business Assets	3.12E-07** (1.25E-07)
Large Livestock	-0.131*** (0.015)
Total Adult Education	0.004*** (0.0008)
Household Size	-0.014** (0.009)
1/Household Size	0.35** (0.128)
Literacy of Father of Head (dummy)	0.034 (0.033)
Father Self-employed Non-agric (dummy)	0.213*** (0.042)
Father Wage Labor Agri (dummy)	0.07 (0.061)
Father Wage Labor Non-agri (dummy)	0.0067 (0.056)
Migrant for non-economic reasons (dummy)	0.035 (0.042)
Upper caste (dummy)	-0.019 (0.039)

*: significant at 10%, **: significant at 5%, ***: significant at 1%.
The regression includes village fixed effects. n=2222