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

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December 2005

Abstract

In the context of firewood collection by rural households in Nepal, we find evidence that firewood collection is increasing with income: poorer households collect less firewood from forests than non-poor households within the same village. This is robust with respect to controls for household size, education, occupation or asset composition, as well as corrections for censoring bias. On the other hand, 'modernization' defined as falling fertility, increasing education and non-livestock-related occupations exercise a strong moderating effect on firewood collection, by raising the shadow cost of collection time. The results suggest that the net effect of economic development on forests in Nepal will depend on the extent to which growth in living standards of the poor is accompanied by modernization.

Keywords: Environment, Poverty, Deforestation.

JEL Classifications: O13, Q50, Q23

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1. Introduction

The connection between poverty reduction and forest degradation is a major issue for environmental policy in less developed countries. Central in those discussions is the idea that poverty forces households to rely disproportionately on environmental common property resources for their survival. Initially proposed by the 1987 Brundtland Commission and the Asian Development Bank (Jalal (1993)), it has subsequently received attention from academics and policy experts (Barbier (1997a, 1998, 1999), Duraiappah (1998), Jalal (1993), Lele (1991), Lopez (1998), Maler (1998), Baland and Platteau (1996), Angelsen and Wunder (2003)). According to this view, halting environmental degradation requires as a prior step the reduction of poverty, via growth or redistributive public policies. A related literature on environmental Kuznets curves examines the connection between per capita income and environmental degradation, mainly on the basis of cross-country macro evidence (Barbier (1997b), Grossman and Krueger (1995), Yandle, Vijayaraghavan and Bhattarai (2002)). This literature suggests the possibility of non monotonic relation (the 'inverted-U') between economic development and environmental degradation, whereby development first increases then decreases strain on environmental resources.

In this paper, we focus on deforestation and firewood use. A central hypothesis consistent with the above literature is the 'energy ladder' model, whereby rising living standards induce households to switch away from traditional fuels, such as cow dung and firewood, to higher quality but more expensive substitutes (Arnold *et al* (2003)).[1] It is based on the notion that poor households rely more on forest firewood *vis-a-vis* modern fuel substitutes purchased from the market, owing to negative wealth effects (since firewood is an inferior and more polluting energy

[1] There is actually 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)).

source) and lower shadow cost of time (the chief cost of collecting forest wood) compared with non-poor households.

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 (2002) or Foster and Rosenzweig (2003)). This paper examines the link between living standards and firewood collection on the basis of household level evidence in rural Nepal from the 1995-96 Living Standards Measurement Survey (LSMS). In the LSMS data, the annual per capita consumption is approximately $250 (in 1995-6 prices), with 43% of households below the $1.5 poverty line (per day per capita). Fuelwood cater to over three quarter of their heating and cooking energy needs (see Table 1 below) and 80% of fuelwood collected directly originate from the forest (Arnold *et al* (2003:12)). Moreover, the Himalayan forests are currently undergoing a process of intense degradation. 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)). These features make Nepal a unique context to study the impact of rising living standards on firewood collection and hence, deforestation.

While there is little doubt that deforestation owes to other causes besides firewood collection, such as timber felling, and conversion of forest into agricultural or pasture land, firewood collection is a major factor behind current forest degradation in the Himalayas.[2] These high levels of degradation are partly irreversible, as fertile topsoil is being washed out by soil erosion in deforested areas. Deforesta-

[2]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 pressures 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. 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. Lopping starts at the lowest branches and proceeds upwards. Since regeneration takes time, lopping at higher height of the trees becomes inevitable as demand for firewood rises. It is common to see severely lopped 'pole-stage' trees in this region, standing tall with only the top crown of branches and a naked trunk below.

tion has immediate consequences for the local population in terms of increased fuel scarcity, reduced supply of fodder and leaf-litter manure. Increased scarcity may 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, implying 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 deforestation in Nepal is a first-order priority for research.

The approach followed in this paper is based on the observation that a large majority households in our sample collect their own fuelwood. Very few of them purchase firewood, and sales of firewood are rare (for a similar observation for Nepal in the 1980s, see Cooke (1998)).[3] And in rural areas, there is hardly any use of modern fuels. Table 1 shows that wood fuel is the main source of energy for cooking and heating for 74% of the households (the other leading sources being cowdung (18%) and leaves or straw (6%)). Only 2.6% of the households used kerosene or gas as the primary source of cooking or heating fuel, and a comparably miniscule proportion used kerosene/gas stoves. In the non-Terai villages, 92 %

[3]Amacher *et al* (1996) provides an 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 a sampling bias, or to the misreporting and unreliable responses which affect interviews on occasional activities. Even in India, the 1993-4 NSS shows that only 13% of the fuelwood consumed throughout the country is purchased (Arnold *et al*, 2003)

of the households collect firewood. The absence or the thinness of fuel markets therefore requires the use of a non-separable model, where the 'price' of firewood corresponds to the unobserved shadow cost of its collection by the household (see e.g. Amacher *et al* (1996)).

The theoretical assumptions underlying the energy ladder model is that low living standards induce greater dependence on forest firewood owing to a combination of wealth and substitution effects. However, further reflection suggests that their validity rely on the existence of affordable fuel substitutes, in the absence of which higher living standards raise energy demand which translate into higher collections of forest wood. Similarly the shadow cost of collection need not be higher among wealthier households, since they can rely more on hired help or family help for collecting from the forest. In that case productive members are not engaged in collecting firewood themselves, so the fact that they have a high shadow cost of time themselves does not imply a high shadow cost of collections for the household as a whole. Contrary to most of the existing literature, we carefully distinguish between the income and the substitution effects. To this end, we propose a measure of the (shadow) cost of collecting firewood which is the product of the shadow cost of time (or shadow wage) and the time necessary to collect one unit of firewood.

It is also not clear what the appropriate notion of poverty is: a low consumption level, or lack of ownership of productive assets such as land or education. Yet whether or not we control for these may conceivably alter the outcome, since assets owned (for a given consumption level) affect the shadow cost of time. In this respect, gross correlations and simple reduced forms are not really informative. One needs to to understand the specific channels by which living standards and firewood collections are related, as well as to measure their relative significance. This knowledge is essential for the formulation of appropriate policies (Cooke *et al* (2001), Arnold *et al* (2003)).

Accordingly, we consider two alternative formulations of the Engel curves relating firewood collection and living standards, which differ in terms of the set of household characteristics we control for. The *conditional* version of the poverty-environment hypothesis (PEH) asserts that a rise in consumption of a household would lower its reliance on environmental resources, holding fixed its education, asset composition, occupation and size. However, growth in living standards often goes hand in hand with the spread of literacy, modern occupations and falling fertility, so the results based on conditional Engel curves may be criticised for missing the effects of such interactions. Accordingly we also examine the *unconditional* version of PEH which asserts that rising consumption standards of the poor would reduce their reliance on environmental resources, without controlling for household characteristics such as education, occupation and size. The indirect effects of rising consumption that occur from induced changes in education, occupations or fertility are then incorporated in the unconditional consumption-firewood collection relationship.

As it turns out, we obtain similar results using either version of the Engel curve. Our results are also robust with respect to corrections for censoring bias (i.e., incorporating the fact that a significant fraction of households do not collect any firewood at all), and possible endogeneity of living standards. Yet another potential concern is that firewood collection and consumption standards may not be causally related, but reflect the effect of some unobserved factor. These may include a variety of unobserved village characteristics, such as the extent of forest degradation (insofar as these are not entirely reflected in collection times which we do control for), village geography, accessibility or infrastructure which affect the availability of substitutes in the village or unobserved household characteristics. We control for unobserved village characteristics with village fixed effects, thus effectively comparing collections of poor with non-poor households within the same village. Our results also turn out to be robust with respect to use of instruments (such as inheritances or parental characteristics) for household living standards.

Section 2 of the paper provides the theoretical framework underlying our specification of the conditional version of the firewood Engel curves. Section 3 describes the data and presents simple OLS unconditional Engel regression results. Section 4 discusses in more detail the econometric problems (omitted variables, endogeneity and censoring biases) these regressions are potentially subject to. It then presents our principal results on the unconditional and the conditional Engel curves, allowing for the endogenous censoring of firewood collection, and controlling for village fixed effects. Section 5 discusses related literature, while Section 6 concludes with a short summary of the main results, and a discussion of shortcomings of our analysis.

2. Theory

In this section, we present the model underlying our estimation strategy. Household i in village v has a utility function

$$U_{iv} = u(F_{iv}, q_{iv}, l_{iv}, h_{iv}, a_v) \quad (2.1)$$

where F_{iv} denotes firewood used by the household, q_{iv} denotes quantity of other goods consumed, l_{iv} denotes leisure time (including time devoted to household tasks), h_{iv} denotes family size, age and sex structure, and a_v represents relevant village characteristics, such as village climate and infrastructure. Each household takes as given village-specific prices of all other goods (denoted p_v), and firewood consumption of the rest of the village. Then given a level of expenditure E_{iv} net of pecuniary costs of firewood, the household has the following indirect utility function

$$W_{iv} = w(F_{iv}, l_{iv}; p_v, E_{iv}, h_{iv}) \quad (2.2)$$

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

Owing to data limitations we will ignore the possibility of firewood markets within the village. About one-tenths of the Nepal LSMS sample households purchase some firewood: the smallness of this sample makes it difficult to study purchase-sale decisions with any accuracy. We therefore assume that firewood used must be entirely collected by the household itself. The cost of using firewood corresponds to the time it takes to collect, valued at the shadow cost of this time to the household. The shadow cost of time depends on the household's assets, employment opportunities, and allocation of its labor across different occupations and tasks. More precisely, the household earns income from allocating family labor across different occupations: $j = 1, 2, ...n$,such as farming, livestock rearing or wage labor. The time spent collecting firewood is proportional to the amounts collected: it takes t_v units of time to collect one unit of firewood, so that the total amount of time required to collect units F_{iv} units of firewood is given by $t_v F_{iv}$.[4]

The total stock of labor of the household is measured by family size (the number of adults plus half the number of children in adult equivalent units); with a slight abuse of notation we shall denote this by h_{iv}. The labor allocated to occupation j is denoted t^j_{iv}, so the time allocation constraint is:

$$h_{iv} = \sum_{j=1}^{n} t^j_{iv} + l_{iv} + t_v F_{iv} \tag{2.3}$$

The budget constraint is given by

$$E_{iv} = \sum_{j=1}^{n} y^j(t^j_{iv}, L_{iv}; n_{iv}, b_{iv}, e_{iv}, p_v, a_v) \tag{2.4}$$

where y^j represents the returns to activity j. They depend, apart from labor allocated t^j_{iv}, on education e_{iv}, land (L_{iv}), nonfarm business assets (n_{iv}) and livestock (b_{iv}) owned by the household. The returns to these activities also depend on village infrastructure, a_v, wages and prices, p_v. Household i in village v has a given set of characteristics $\theta_{iv} \equiv (h_{iv}, L_{iv}; n_{iv}, b_{iv}, e_{iv})$ and takes as given village variables $V_v \equiv (p_v, a_v, t_v)$. It selects firewood collection F_{iv} and labor allocation t^j_{iv}, to maximize utility (2.2) subject to constraints (2.3) and (2.4). Letting c_{iv} stand for the shadow cost of time when collecting firewood, we obtain the household demand for firewood:

$$F_{iv} = F(E_{iv}, h_{iv}; c_{iv} t_v, a_v) \tag{2.5}$$

The shadow cost of time of firewood collection c_{iv} equals the marginal utility of leisure, which depends on the time allocated to various income earning activities, determined simultaneously with firewood collection. In the reduced form version of the model, the allocated time to various activities by the household depends on

[4] The model can be easily extended to the case where the time taken to collect firewood is itself endogenous and depends on the total amounts collected in the village. Similarly, one can also extend the model to allow for the existence of collective norms relative to the amounts collected in the village.

household characteristics: for instance, a household with more farm or nonfarm assets devotes more time to those activities (under the plausible assumption of complementarity between asset ownership and returns from the corresponding occupation), reducing time available for collecting firewood, grazing livestock and other household tasks.[5] Taking a linear approximation, we can then express the shadow cost as a function of household and village characteristics and household expenditures :

$$c_{iv} = \delta_1 + \delta_2 h_{iv} + \delta_3 L_{iv} + \delta_4 n_{iv} + \delta_5 b_{iv} + \delta_6 e_{iv} + \delta_7 E_{iv} + \delta_8 V_v + e'_{iv} \tag{2.6}$$

where the coefficient $\delta_{3,}$ $\delta_{4,}$ and δ_6 are expected to be positive, while δ_5 is expected to be negative, as livestock grazing is complementary to collecting firewood. The sign of δ_7 can be positive or negative, depending on the complementarity between leisure and expenditures on all other goods. Taking a linear approximation of (2.5) and using (2.6), and allowing for the possibility of corner solutions, we then obtain:

$$\begin{aligned} F_{iv} &= \max[0, \theta_0 + \theta_{11} E_{iv} + \theta_{12} E_{iv}^2 + \theta_2 hh_{iv} + \theta_3(\delta_1 + \delta_2 h_{iv} + \delta_3 L_{iv} \\ &\quad + \delta_4 nfb_{iv} + \delta_5 b_{iv} + \delta_6 e_{iv} + \delta_7 E_{iv} + \delta_8 V_v + e'_{iv}) t_v + \theta_4 a_v] \end{aligned} \tag{2.7}$$

which can be rewritten as:

$$\begin{aligned} F_{iv} &= \max[0, \beta_0 + \beta_{11} E_{iv} + \beta_{12} E_{iv}^2 + \beta_2 h_{iv} \\ &\quad + \beta_3 E_{iv} t_v + \beta_4 \theta_{iv} t_v + \beta_5 h_{iv} t_v + \beta_v + e_{iv}] \end{aligned} \tag{2.8}$$

where the error term e_{iv} absorbs the former error term as well as all the ignored interaction and higher order terms resulting from the linear approximation.[6] β_v

[5] The alternative would be to estimate explicitly a household production function from which to extract measures of the marginal productivity of the members of the family (Amacher *et al* (1996)). We also did our regressions using this procedure, with similar results as the ones reported here.

[6] In particular, we have dropped the interaction between collection time and household size, age and sex structure, which may be believed to be important. These interaction effects turned out to be insignificant, so we dropped them to minimize collinearity with the household size, age and sex structure levels.

($= \theta_3\delta_1 t_v + \theta_3\delta_8 V_v t_v + \theta_4 a_v$) is a village fixed effect which includes all the village parameters affecting the household demand for firewood, including the amount of time necessary to collect one unit of firewood in the village, and the village determinants of the shadow cost of household's time. The conditional Engel curve represented by (2.8) relates intra-village variations in consumption levels and household characteristics with firewood collection. We can interpret the terms involving consumption in (2.8) as the pure wealth effect on collections, the interaction term $E_{iv}t_v$ with wealth effects on the shadow cost of time, and the interaction term $\theta_{iv}t_v$ as the effect of asset ownership on the shadow cost of time.

The unconditional version of the Engel curve is estimated using the corresponding equation, without controlling for household characteristics such as education, occupation and size:

$$\begin{aligned} F_{iv} &= \max[0, \phi_0 + \phi_{11}E_{iv} + \phi_{12}E_{iv}^2 \\ &\quad +\phi_2 E_{iv}t_v + \phi_v + \acute{e}_{iv}] \end{aligned} \tag{2.9}$$

3. Description of Data

3.1. Descriptive Statistics

Tables 2 and 3 provide descriptive statistics of household and village characteristics respectively. The World Bank Living Standards Measurement Survey (LSMS) for Nepal interviewed households concerning their production and consumption activities for the year 1995-96. It covered 274 wards (villages), of which 215 are rural. We use only the data for the 2712 households in the rural area where firewood collection is more likely to be important, and in order to avoid complications from urban-rural heterogeneity. Nearly one third of the sample did not collect firewood at all. Nearly 84% of non-collectors are concentrated in the lower altitude Terai region where deforestation has been especially pronounced. On average a household collected 5.8 bharis (i.e., a headload) or bundles of firewood a month. Households mentioned adults as the principal collectors of firewood, and females somewhat more important than males in this respect (average number of adults collecting per household was 1.56, of which female adults accounted for 0.94). 77% of the households collected firewood from a government or community forest, with the remaining households collecting either from their own lands or other sources (such as from roadsides). The average time reported to collect one bundle of firewood was 5.27 hours.

The mean annual consumption for a household was Rs. 35,000. Given that the average household size was 4.4 (in adult equivalent units with members below 12 being counted as half an adult), the corresponding annual per capita consumption was approximately $250 (in 1995-96 prices). The average poverty gap (relative to a poverty line of 1$ per day per capita) was 14%, while that relative to 1.50$ per day per capita was 43%, indicating high levels of poverty. 13% of the households were headed by women (either widowed or spouses working outside). The majority were engaged in self-employed agricultural activities and livestock rearing. Principal assets consisted of cultivated land, livestock and nonfarm business assets. Education levels were low: 70% of household heads had no education. On average, 8% of household members suffer from some form of chronic illness.

The villages varied considerably with regard to elevation, which ranges from 190 to 17000 feet above sea level. The low lying Terai region, usually defined by an elevation of up to 1000 ft above sea level, has experienced the greatest deforestation since the 1950s. Table 4 shows the principal characteristics of the Terai and the non-Terai regions in the LSMS sample. Approximately 60% of the households in the sample are from the non-Terai region. The two regions do not differ significantly with respect to average consumption, household size or education standards. However, two-thirds of Terai households do not collect firewood at all (compared with 8% in the non-Terai), and the remaining collect one-third of the amounts collected by non-Terai households. This is despite the fact that collection times are approximately the same in both regions. However, fuel needs differ a lot between the two regions, as the Terai benefits from a subtropical 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. This creates a large difference between the two regions, with a very important need of heating fuel in the non-Terai area, particularly in the winter season. The two regions also differ significantly with regard to occupational structure: despite a higher value of farm land cultivated and a lower value of nonfarm business assets owned, a higher fraction of household employment in the Terai is in the non-farm sector.

The government of Nepal introduced a community forestry scheme in 1993, handing over forest areas to be managed by local communities.[7] In our sample, 11% households on average reported collecting from a community forest; 43% of the villages had at least one such household in the sample. Unfortunately the LSMS household questionnaire did not include a direct question about membership. Consequently we cannot include this information among the set of household characteristics. We do, however, include a village dummy variable where a user group is defined to exist if at least one household reported collecting from a community forest. Some anecdotal evidence suggest that the rich are more powerful in the forest user groups and may be able to collect more. In one of the later extensions of our model we therefore include the interaction of consumption with the village dummy for existence of a community forest.

3.2. Simple Representations of the Consumption-Collections Relationship

The raw data shows that for households who collect firewood, collections do not decrease with consumption expenditures of households within the same village. Figure 1 plots the 95% confidence band for mean deviation of firewood collection

[7] 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.

from the village mean for twenty different percentile groups (each corresponding to a five percentile group) against corresponding deviations in consumption levels of these different groups. It shows no support for the energy ladder model: groups in the lowest percentile groups collect significantly less (with a difference of more than three bharis, which substantially exceeds the width of the 95% confidence band).

Figure 2 displays the corresponding intervillage consumption- collection relationship. It plots mean village consumption against mean consumption levels. Here the highest levels of collection are manifested in villages with the lowest and highest consumption levels, with no overall trend.

Table 5 presents results of simple OLS regressions, using household collections as the dependent variable. The first one includes consumption expenditures and their square, while the second also includes collection time and the interaction between consumption and collection time. Measures of education, occupational structure and demographics are excluded. So these are unconditional Engel curves. The estimated Engel relationships display a positive relationship between consumption and collections over most of the range of consumption, except at the very top where there is a tendency for the slope to flatten and turn negative.[8] So there appears to be no evidence in favor of the hypothesis according to which poorer households collect more firewood. Note also the estimated interaction between consumption and collection time is positive and significant, contrary to the prediction that shadow cost of collection time is higher for households with higher living standards.

4. Unconditional and Conditional Engel curves

The OLS regressions reported in Table 5 are subject to a number of econometric problems. First is the problem of potential endogeneity of consumption levels. Unobserved village variables such as the size of the forest stock, climate, urbanization, village-level collective action or access to fuel substitutes can jointly affect

[8] The turning point occurs around 150000 Rs, which corresponds to the top percentiles of the distribution.

income and consumption levels as well as collection activities. One solution is to use village fixed effects that controls for unobserved village attributes.[9] Nevertheless even the intravillage regression may be subject to endogeneity bias owing to omission of household characteristics such as chronic illnesses that affect both consumption and collections, an issue we explore below.

The second problem arises from censoring, since between a third and quarter 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 we use the semiparametric estimator proposed by Honore (1992) for censored data with fixed effects.

In table 6, we present the unconditional Engel regressions with village fixed effects, which corresponds to equation (2.9). These estimates incorporate the indirect effects of consumption on collections via its impact on education, asset ownership and fertility. The two columns show the estimates with a quadratic and fourth order polynomial specification respectively. The pattern of the unconditional predictions is similar to those of the conditional predictions (see below) and of the above OLS (unconditional) predictions: collections are rising and concave in consumption, with a turning point occuring at the very top end of the distribution. Moreover, there is no evidence of a higher cost of collection effect for wealthier households.

Table 7 presents the corresponding estimates of the conditional Engel curves (eq. (2.8)). We omit to report in Table 7 the coefficients associated with the household age and sex structure variables that were included in the regressions, but turned out to be low and insignificant. Regression 7.1 excludes interaction between consumption and collection time, while 7.2 shows the effects of including this interaction. The remaining specifications check for the robustness of our

[9]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 (see also Dewees (1989) and Cooke *et al* (2001)).

results. Regression 7.3 incorporates the non-interacted assets in the specification. Regression 7.4 allows for potential endogeneity of consumption at the household level. Instruments for consumption include ethnicity, age of head of household, land inherited by the head, education and occupation of parents of the head, assuming therefore that these variables do not have a separate independent impact on firewood collections. This estimation uses predicted consumption from the reduced form as a regressor (in place of actual) and can accordingly be interpreted as a measure of permanent consumption expenditures. The effect of occupational structure on collections is further explored in regression 7.5 which replaces the interactions of collection time with different assets by its interaction solely with the fraction of household working hours in nonfarm occupations. Regression 7.6 corresponds to the case where fraction of chronically ill members is added to the basic model 7.1. Finally, 7.7 adds consumption interacted with a village dummy for the existence of a forest-user group. Implied elasticities and effects of one standard deviation changes in each variable on latent collections are shown in Table 8 for regression 7.1.

Overall, the evidence does not support the conditional version of the energy ladder model: firewood collections are increasing in consumption expenditures.[10] The estimated elasticity of collections with respect to consumption is positive and smaller than one. Hence the reliance on firewood collections expressed as a proportion of consumption is high at the bottom end of the distribution, and falls thereafter. The latter is consistent with the numerous studies in Asia and Africa documenting that the ratio of common property resource use to consumption is highest among the poor (e.g., Beck and Nesmith (2001), Angelsen and Wunder (2003)). In this sense it is true that the poor depend more than the nonpoor on firewood. Yet this does not imply that a reduction in poverty would reduce pressure on the forests, since a rise in consumption of the poor would raise their collections in absolute terms, but less than proportionately. The relevant criterion is whether the elasticity is positive, not whether it is less than one. The latter fact

[10]But it is insignificant in the endogenous consumption case, which is not surprising as predicted consumption is likely to be more noisy due to the use of predominantly categorical variables (with the exception of inherited land).

is pertinent instead to the distributional impact of deforestation: a less than unit elastic demand for firewood implies that the (proportional) impact of deforestation on welfare will be greater for the poor than for the nonpoor.

The estimates of the conditional Engel curve in Table 7 separate the effect of rising consumption into the wealth and cost-of-collection effects. The wealth effect is rising. Even in the case of endogenous consumption, the estimates though insignificant also imply a positive wealth effect. Hence irrespective of how consumption is measured, there is no evidence in favor of negative wealth effects on degradation. An important cause is the restricted use of modern fuel substitutes that was shown in Table 1, owing to restricted access or high cost of these substitutes. As a household's living standards rise, its energy needs rise; in the absence of reasonably priced fuel substitutes they are forced to rely on higher collections of firewood from the forest.

The relationship between living standards and firewood collection is further explored in Figure 3. From the coefficients obtained in 7.1 (including those related to the cost of collection), we predicted firewood collection excluding the impact of consumption and computed the difference between the actual and the predicted levels of collection. We then regressed non-parametrically these differences on consumption (see Yatchew, 2003) and the results obtained are presented in Figure 3. (We ran other estimates, using alternative specifications of the basic model, including a quartic model in consumption, with no substantial change on the nonparametric relation obtained.) As one can see from Figure 3, for 99.9% of the households (which corresponds to an income level below 250000 Rs), the relation between collection and consumption is increasing and accelerates at the top end of the distribution (over 200000 Rs, which corresponds to the top 0.4% of the income distribution). It levels off only at the very top end (at around 13 bharis per month). Collections are multiplied by five when consumption changes from 35000Rs (the average consumption level) to 250000 Rs.

The other source of evidence against the conditional version of the energy ladder model concerns its predictions concerning the shadow cost of collection time. The interaction of consumption with collection time is negative but insignificant. So there is no evidence that higher living standards per se raises the shadow cost of collection time. Apart from low complementarity between leisure and consumption expenditures, a possible reason lies in the allocation of collection responsibilities within the household. The Nepal LSMS contains information about the collectors of firewood within the household. Table 9 presents this information for households with a size between 3 and 5 effective members (the picture is similar for smaller and larger households). For each consumption quartile it presents the per household reliance on different types of household members. Households in higher consumption quartiles rely less on the household head and more on children and others (primarily servants and extended family members). [11]

Collections significantly increase in household size, with a high elasticity of 0.5. Since the regression already controls for consumption, this suggests the role of increasing stock of household labor available for collecting firewood, and increased fuel need (e.g., for heating, which is presumably not reflected in measured consumption). It may also be related to the household public good nature of most of the services produced by firewood (heat, cooking fuel). Apart from consumption and household size, the significant determinants of firewood collection are interactions with collection time of land, livestock, and education of head of household. Since the regression already controls for the wealth effect of asset ownership by including consumption, these interactions can be interpreted as effects of occupational structure on the shadow cost of collection time. These effects are what one would intuitively expect: higher livestock reduces the shadow cost of time collecting firewood (reflecting complementarity between livestock grazing and firewood collection), while greater ownership of farm land or education raises the shadow cost of collection time. The coefficients associated with the existence of a forest user group (interacted with consumption), and the fraction of chronically ill members in the household, while positive, are both insignificant.[12]

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

[12] Our results concerning the role of forest user groups are weaker than those reported by Edmonds (2002). He finds a robust 11-14% reduction in firewood collection at the household level with respect to formation of forest user groups in the LSMS data for the Arun Valley. Similarly, Somanathan *et al* (2005a) find that village forest management councils in the Indian

To sum up, our results suggest a sharp increase with respect to rising living standards. Ignoring the censoring effects, the cross-sectional elasticities provided in Table 8 can be used to extrapolate future time trends. If we assume that living standards in Nepal are to increase by one standard deviation (i.e., 78%) over the next 20 years, firewood collections in the absence of other changes will increase by 26%. To neutralize this so that collections remain constant, (1) the education of the head should increase at the same time by 9 years (corresponding to 3 SD), or (2) household size should fall by 23% (slightly more than one adult equivalent), or (3) all households should simultaneously accumulate Rs 73000 worth of non-farm business assets (equal to two years of current consumption expenditures) while years of schooling of the head rises by 6 years. Simple computations reveal that the impact of a one-year rise in education of the head would be wiped out by an increase in living standards of 5.7%, or a 5% increase in household size. As a result, the impact of future increases in living standards will depend crucially on the type of development: pressures on Nepal's forests arising from firewood collection may not rise if growth in living standards are accompanied by significant increases in education and farm productivity. Absent the latter, firewood collections are likely to increase appreciably.[13]

The effect of occupational structure on collections is further explored in equation 7.5 which replaces the interactions of collection time with different assets by its interaction solely with the fraction of household working hours in non-farm occupations. This is negative and strongly significant. Hence a greater reliance on non-farm occupations significantly increases 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 the Appendix. Households whose heads are more educated, male, and whose parents were also employed in non-farm occupations tend to be more involved in non-farm occupations.

Himalayas do slightly better than state or unmanaged forests. (See also Heltberg (2001)).

[13] Of course, this discussion ignores the countervailing impact of rising collection times following the increased fuelwood scarcity.

To check that the foregoing results are not affected by aggregation of regions with major differences in their economic and ecological characteristics, as well as their fuel needs, we re-estimated regression 7.1 separately for Terai and non-Terai households, and within the non-Terai area separately for villages below and above 1000 feet. Due to missing values, the regression sample for Terai reduced to only 478 observations while that for non-Terai reduced to 1471 observations. 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 92% of the households collect firewood (censoring is much higher in the Terai area, as revealed by Table 4), fuelwood markets are almost non-existent, and fuel subsitutes are not easily available. The results are reported in Table 10. Similar to the pooled data, the estimated relationship with consumption is increasing and concave within both regions and statistically insignificant for the Terai area. In other words there is no evidence in any region in favor of the energy ladder hypothesis. The coefficients estimated for the Terai area are all insignificant, even though consistent in sign with those estimated in the pooled model, or in the non-Terai area. In the non-Terai area, and particularly above 1000 feet, the coefficients estimated are strikingly similar to the ones obtained with the pooled data. 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 in high altitude villages.[14] These non-farm business assets possibly pertain to the trekking and tourism industry which has accelerated since the 1950s and is largely concentrated in the non-Terai region of the Nepalese Himalayas.

Finally, it must be noted that the exclusion of fuel substitutes in the regressions above tends to bias the relationship between consumption and fuel consumption downwards, not upwards: we underestimate the true energy requirements of the richer households. Related, we focused on firewood collected by the household, and excluded the amounts that were sold or bought. As discussed in the introduction, such sales are too rare, and we do not have enough information in the LSMS

[14]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.

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 again biases the relation between firewood consumption and living standards against our central results: poorer people report more collections than they consume, and the richer ones report less than they consume.

5. 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 positive but less than unitary income elasticity of firewood collections. Yet the concern, expressed by the energy ladder hypothesis, or more broadly the environmental Kuznets curve, is about the change in the use of those resources in absolute terms, not in proportion to consumption. A falling proportion is consistent with a rising dependence on these resources in absolute terms.

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 subject to potential biased from omission of 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. This supports the energy ladder hypothesis as it suggests that fuelwood is generally an inferior good. However, Cooke *et al* (2001) also note that the income elasticities might not be constant with 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, provide support for the hypothesis that 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)). Adhikari *et al* (2004) use household data on a small sample from Nepal to explore the relationship between the use of collective forests and household characteristics, including income. Their main results are similar to the ones presented in this paper, since they also find a strong and positive correlation between income and the amount of resources drawn from the village forests (fuelwood, but also leaf litter, tree fodder and grass fodder). The estimated direct price (or cost of collection) elasticities for firewood 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)). Cross-price evidence however shows very little substitution between fuelwood and other fuels (Cooke *et al* (2001)).

Many of these studies however suffer from a number of weaknesses. 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)). Many 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.[15] 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, and a measure of income. They however do not interact those two variables 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.

More importantly, they do not control for various biases at the village and household levels, which may be partly responsible for the discrepancy observed between these results and ours. Thus, 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.

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 PEH hypothesis 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 also subject to other sources of measurement errors. For instance, satellite images relay on aerial pho-

[15] A difficulty arises because the time to collect is not observed for non-collecting individuals. In this paper, we chose to use village average of collection time, conditional on reporting, as a good measure of the time taken by an 'average' villager to 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. Another possibility is to use individual collection time reported, and use for non-collecting households a predicted collection time as a function of households and village characteristics. Similar results as the ones reported here obtain under this alternative. Another possibility, followed by Pattanayak *et al* (2004) is to truncate the sample, thereby missing households who dont collect, which would be wholly inappropriate for our purpose.

tographs of forest cover, and thus cannot accurately portray degradation in the form of excessive lopping beneath the cover, which our measure will succeed in incorporating.

Pitt (1985) estimates demand for alternative fuels using household level data for Indonesia, where fuel markets are relatively well developed.[16] 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 context where market for fuelwood, charcoal and kerosene are well-developed. As Indonesian households are much richer than their Nepalese counterparts, it is possible that the relation between income and firewood consuption is positive at low levels of income, but negative at higher levels, as suggested by the environmental Kuznets curve. The role of the development of fuel markets in this context remains to be explored.

Chaudhuri and Pfaff (2002) and Foster and Rosenzweig (2002) estimate Engel relationships using household level data with village fixed effects, for Pakistan and India respectively. Though based on somewhat different ecological contexts in comparison to the Nepal Himalayas, Chaudhuri and Pfaff find an inverse U-shaped relation (also consistent with the environmental Kuznets curve) between firewood use and incomes in the 1991 Pakistan household data (which combines rural and urban households), while Foster and Rosenzweig find a small (but statistically significant) negative effect in cross-sectional Indian rural household data from 1982. The differences between these countries may arise from different access to alternative fuels, education levels and levels of per capita income. For instance, the switch to modern fuels in Pakistan identified by Chaudhuri and Pfaff occurs particularly among urban households, where fuel substitutes are more easily available than rural areas. Rural households also used kerosene and electricity in cooking more frequently. Thus, the proportion of rural households using kerosene

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

and electricity as primary source of fuel for cooking in Pakistan was 9%, compared to 2.6% in Nepal. Educational levels in rural Pakistan were substantially above those in Nepal: e.g., the average years of schooling of household heads in the rural Pakistan sample was 6.3 years, in comparison to 1.87 years in the rural Nepal sample. Moreover, some of our estimated conditional regressions also showed an inverse-U tendency at the very top end of the distribution (after the 99.6% income percentile). This suggests that the environmental Kuznets curve may apply in Nepal, but only for a very small number of households (0.4%). The vast majority of them are still operating on the upward sloping segment.

Other literature on firewood collection in Nepal stresses the role of nonagricultural labor markets and forest property rights in specific parts of the country. Amacher, Hyde and Kanel (1996) and Bluffstone (1995) discuss evidence concerning significant elasticities of labor supply and fuelwood collection activities of Nepalese households with respect to shadow wages in the low lying Terai region, though not at higher altitudes. This is consistent with our findings concerning the impact of nonfarm employment opportunities.

6. Concluding Comments

Our principal findings are the following. The relationship between consumption and firewood collection in Nepal is for most part increasing and concave. We decomposed the (conditional) Engel effect into a wealth effect and a cost of collection effect. The wealth effect tended to be positive and dominant of the two: the households in our sample manifested no switch to alternative fuels with rising consumption levels. The cost of collection, which consists of the time taken to collect firewood from the forest valued at the shadow cost of the household's time showed no significant variation with consumption standards, and had therefore little impact. Holding consumption levels fixed, higher levels of literacy and nonfarm employment were associated with significantly lower firewood collections (via their effect on the shadow cost of collection time). Firewood collection also increased with household size.

Overall, thus, rising living standards have large and significantly positive effects on firewood collection and consumption. Negative wealth effects operating through the shadow cost of collection time do not play a major role in mitigating this relation. On the other hand, 'modernization' defined as falling fertility, increasing education and land related occupations that are not livestock dependent do exercise a strong moderating effect on firewood collection, by raising the shadow cost of collection time. This suggests that the net effect of economic development on forests depends primarily on the extent to which growth in living standards is accompanied by moderating forces related to modernization.

We also found that Nepalese households do not use substitutes to firewood, apart from cowdung, leaves and twigs. This is in contrast with studies in other areas, such as Pakistan (Chaudhuri and Pfaff (2002)) or Indonesia (Pitt (1985)). The low use of other fuel sources in Nepal can be explained by at least two features. First, the greater need for heat in the winter season, particularly in the non-Terail, 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.

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 absence of information on forest stock and quality: do differences in firewood collections drive deforestation? Or are other factors, such as household demand for timber, changes in forest area resulting from conversion to agricultural land, private concessions to timber merchants, and illegal felling more important? To assess this question we would need data concerning changes in forest stock over time, for instance from 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. In our ongoing extension of this project to villages in the Indian Himalayas, we are attempting to gather better information on all these dimensions. Contrasting the experience of different Indian states, and of these with Nepal will also be interesting.

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Acknowledgement

We thank Giovanna Prenuschi, the Central Bureau of Statistics in Nepal and the Poverty and Human Resource Division of the World Bank for making the LSMS data available to us. For useful comments we are grateful to Judy Dean, Eric Edmonds, Marcel Fafchamps, Andy Foster, Bo Honore, Vegard Iversen, Larry Kotlikoff, Sylvie Lambert, Kaivan Munshi, Mark Rosenzweig, Forhad Shilpi, Chris Udry, participants at the September 2001 Santa Fe Institute conference on Inequality, Collective Action and Environmental Sustainability, at the September 2001 Aupelf-Uref Montreal conference, at the January 2002 Costa Rica meetings of the MacArthur Inequality network, and at the University of East Anglia. Shiv Saini, Amaresh Tiwari and Nobuo Yoshida provided excellent and untiring research assistance. Alfredo Cuecuecha also provided useful support. This research was supported by the National Science Foundation (NSF grant no. SES-0079079) and the MacArthur Foundation network on Inequality and Economic Performance. This research is also part of the Belgian Program on Interuniversity Poles of Attraction initiated by the Belgian State, Prime Minister's Office, Science Policy Programming.

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

Table 1: Percentage of households using a type of fuel as a primary or secondary source of energy

Variable	Mean	Standard Deviation	Minimum	Maximum	Number of Zeroes	Number of Observations
Firewood Collected (# bharis/month)	5.78	5.76	0	35	807	2670
Annual Cons. Expenditure (10^6 Rs.)	0.0353	0.0276	0.0029	0.4459	0	2712
Amount of land cultivated (Has)	0.55	1.14	0	14.22	684	2348
Value of Non-Farm Business Assets (Rs.)	7940	73167	0	250000	2260	2712
Fraction of Household Members Self-Employed in the Non-Agric. Sector	0.08	0.21	0	1	2071	2673
Fraction of Household Members Working as Wage-Earners in the Agric. Sector	0.15	0.25	0	1	1590	2673
Fraction of Household Members Working as Wage-earners in the Non-Agric. Sector	0.11	0.20	0	1	1705	2673
Number of Cows Owned by a household	3.72	3.12	0	27	241	2439
Household Size (Adult Equiv.)	4.41	2.06	0.00	20.4	25	2712
Years of Education of the Hh Head	1.87	3.39	0	17	1912	2712
Fraction of households which are Female-Headed	0.13	0.34	0	1	2361	2712
Fraction Children in a household	0.26	0.20	0	0.8	741	2712
Fraction Prime-Age Males in a Household	0.35	0.18	0	1	133	2712
Fraction Prime-Age Females in a Household	0.35	0.17	0	1	69	2712
Fraction Old Men in a household	0.02	0.08	0	1	2423	2712
Fraction of Hh Members with Chronic Illnesses	0.08	0.16	0	1	1877	2712

Table 2: Descriptive statistics of household characteristics (whole sample)

Variable	Mean	Standard Deviation	Minimum	Maximum	Number of Zeroes	Number of Observations
Average Poverty Gap ($1 per day)	0.13	0.11	0.00	0.48	19	215
Fraction of Households Reporting Collecting Firewood from a FUG forest	0.11	0.19	0	1	125	215
Mean Collection Time in the village (hrs/bhari)	5.27	2.44	0.50	12.86	0	184
Elevation above sea level (Km)	0.94	0.94	0.058	5.29	0	215

Table 3: Descriptive statistics of village characteristics (whole sample)

	Terai	Non-Terai
Number of Households	1054	1658
Mean Annual Household Consumption Expenditures (10^6Rs)	0.0345 (0.0274)	0.0358 (0.0277)
Mean Household Size	4.61 (2.25)	4.27 (1.96)
Mean Cultivated Landholding (Has)	1.04 (1.50)	0.25 (1.70)
Mean Value of Non-Farm Assets	5768 (39375)	9320 (88139)
Mean Years of Education of the Hh Head of Household Head	2 (3.44)	1.78 (3.35)
Mean Number of Cows Owned	2.98 (2.94)	4.14 (3.14)
Mean Fraction of Household Time Given to Non-Farm Occupations	0.22 (0.29)	0.17 (0.26)
Proportion of Households not Collecting	0.65	0.08
Mean Collection per Collecting Household	2.37 (4.04)	7.96 (5.64)
Mean Collection Time per Collecting Household	5.0 (3.07)	5.03 (2.67)
Standard deviations in parentheses		

Table 4: Descriptive statistics of household characteristics in the Terai and the Non-Terai samples

Dependent Variable: Firewood Collection by Household (# bharis/month)		
Consumption Expenditures	65.27*** (7.05)	82.35*** (12.91)
Square of Consumption Exp.	-193.84*** (33.05)	-222.18*** (34.95)
Collection Time		0.03 0.08
Consumption Exp.*Collection Time		3.26** (1.81)
Number of Observations	2670	2292
R2	0.03	0.04
*: significant at 10%, **: significant at 5%, ***: significant at 1% Standard errors in parentheses		

Table 5: Unconditional Engel curves: OLS estimates

Dependent Variable: Firewood Collection by Household (# bharis/month)		
	6.1	**6.2**
Consumption Exp.	116.06*** (28.28)	238.78*** (60.74)
Consumption Exp.^{2}	-352.33*** (126.59)	-2365.64* (1315.84)
Consumption Exp.^{3}		10074.66 (10405.98)
Consumption Exp.^{4}		-14683.63 (24442.65)
Consumption Exp.* Collection Time	-3.49 (4.67)	-4.12 (3.49)
Number of observations: 2292, Standard errors in parentheses. All regressions include a village fixed effect. The * in the Variable column denotes interactions p-value for chi-sq test for joint significance =0.00 *: significant at 10%, **: significant at 5%, ***: significant at 1%		

Table 6: Unconditional Engel curves: Trimmed LAD Estimates

Dependent Variable: Firewood Collection by Household (# bharis/month)							
	7.1	7.2	7.3	7.4	7.5	7.6	7.7
	Basic model	with interaction	with assets	with cons. instrumented	with non-farm occupations	with chronic illnesses	with forest user group
Consumption Exp.	52.24**	69.24**	51.63**	69.09	41.11**	51.92**	45.61**
	(22.96)	(28.27)	(21.86)	(49.99)	(18.01)	(22.92)	(21.43)
Consumption Exp.	-167.37	-162.83	-168.72	-358.11	-168.27	-166.21	-161.4
Square	(163.94)	(155.77)	(151.83)	(367.37)	(125.13)	(163.51)	(0.35)
Consumption Exp.*		-3.74					
Collection Time		4.00					
Land Owned*	-0.04**	-0.03**	-0.23***	-0.04**		-0.04**	-0.03**-
Collection Time	(0.02)	(0.02)	(0.08)	(0.02)		(0.02)	(0.02)
Nonfarm Business Assets*	-1.13	-1.04	-0.46	-0.40*		-1.15	-1.31
Collection Time	(1.19)	(1.13)	(2.26)	(0.21)		(1.19)	(1.29)
Cows Owned*	0.03***	0.03***	0.02	0.02**		0.03***	0.03***
Collection Time	(0.01)	(0.01)	(0.02)	(0.01)		(0.01)	(0.01)
Years Schooling of Head*	-0.02**	-0.02***	-0.00	-0.03**		-0.02***	-0.02***
Collection Time	(0.01)	(0.01)	(0.02)	(0.01)		(0.01)	(0.01)
Non-Farm Occupation*					-0.005***		
Collection Time					(0.001)		
Household Size	0.93***	0.95***	0.95***	1.03***	1.09***	0.94***	0.93***
	(0.24)	(0.24)	(0.24)	(0.37)	(0.22)	(0.24)	(0.24)
Household Size	-0.04**	-0.04**	-0.04**	-0.05**	-0.04**	-0.04**	-0.04**
Square	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)
Proportion of hh members						0.82	
with chronic illnesses						(0.78)	
Consumption*Forest							52.48
User Group							(56.18)
Land owned			1.04**				
			(0.47)				
Non-farm business assets			-4.00				
			(8.74)				
Cows Owned			0.07				
			(0.11)				
Years Schooling of Head			-0.14				
			(0.10)				
Number of observations	1949	1949	1949	1735	2258	1949	1949

The * in the Variable column denotes interactions. P-value for chi-sq test for joint significance =0.00

All regressions include a village fixed effect, and household age and sex structure variables: female head, fraction of children, young women, young and old men.. *: significant at 10%, **: significant at 5%, ***: significant at 1%, Standard errors in parentheses

Table 7: Conditional Engel curves: Trimmed LAD Estimates

Firewood Collection Elasticities					
	Derivative (abs. t-value)	Elasticity at 30%	Elasticity at 50%	Elasticity at 75%	Effect of one S.D. increase (95% CI =+/-)
Consumption (Rs. mill.)	49.95 (3.08)	0.28	0.24	0.20	1.44 (0.91)
Land owned	-0.16 (1.98)	0.00	-0.00	-0.01	-0.16 (0.15)
Nonfarm Business Assets	-5.44 (0.92)	0.00	0.00	0.00	-0.44 (0.94)
Number of cows owned	0.15 (3.15)	0.07	0.07	0.07	0.47 (0.29)
Years Schooling Head	-0.15 (3.22)	0.00	0.00	-0.04	-0.50 (0.31)
Household Size	0.70 (5.30)	0.66	0.49	0.31	1.37 (0.51)
Derivatives and the effect of one SD increase are evaluated at the median.					

Table 8: Estimated Firewood Collection Elasticities from the Conditional Engel Curves (Basic Model 7.1)

Probability that a Particular Household Member Participates to the Collection of Firewood per consumption quartile				
	Bottom Cons. Exp. Quartile	Second Cons. Exp. Quartile	Third Cons. Exp. Quartile	Top Cons. Exp. Quartile
Household head	0.72	0.65	0.61	0.53
Spouse	0.64	0.65	0.73	0.64
Children	0.44	0.61	0.59	0.67
Grandchildren	0.01	0.02	0.03	0.04
Others	0.20	0.19	0.28	0.30

Table 9: Collection Patterns across Different Household Members by Consumption Quartiles (for an Effective Household Size between 3 and 5)

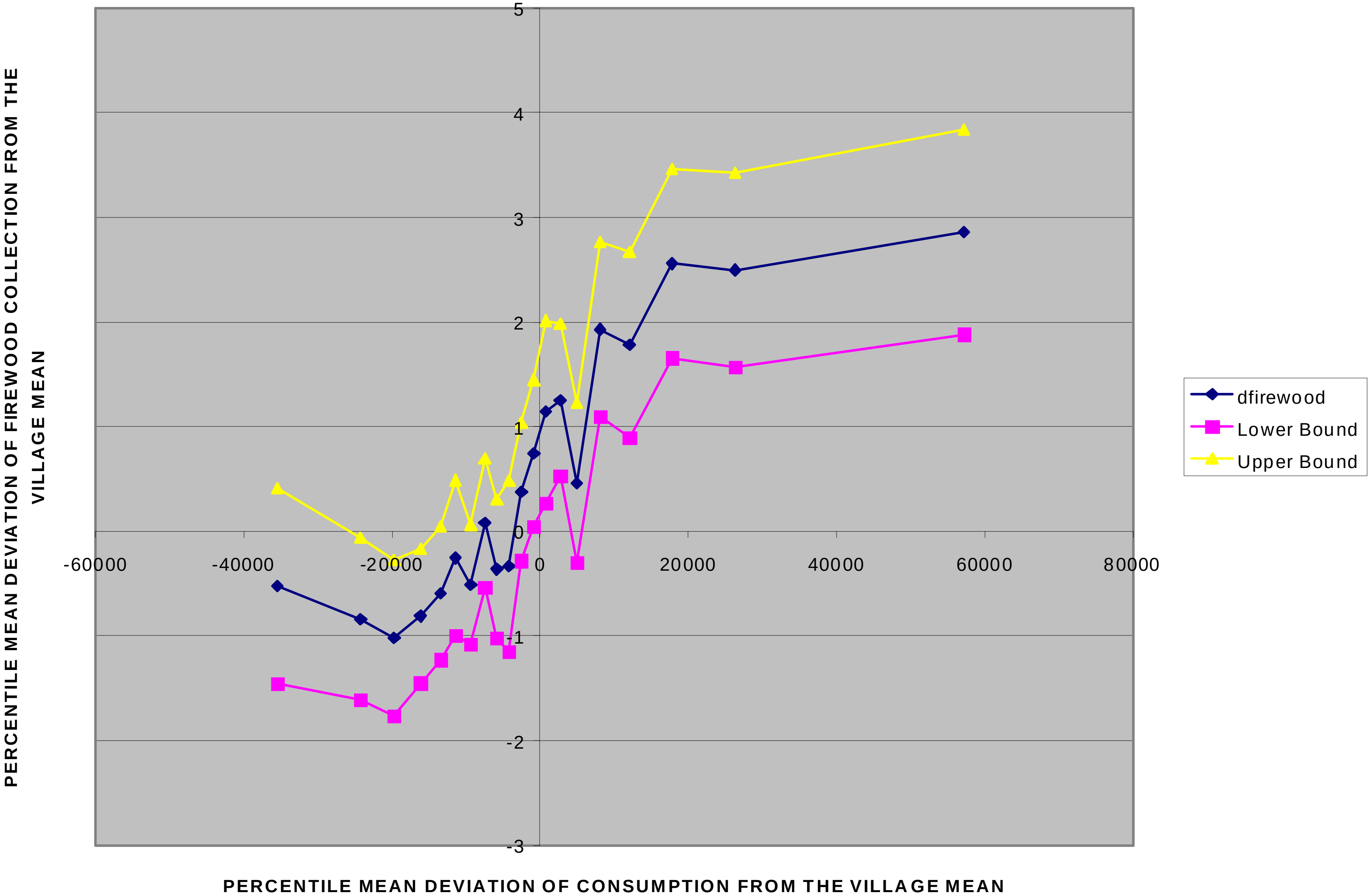
Dependent Variable: Firewood Collection by Household (# bharis/month)				
	Terai	non-Terai	between 1000 and 3000 feet	above 3000 feet
Consumption Exp.	46.08 (31.01)	61.07** (24.87)	107.55** (48.90)	51.84*** (13.58)
Consumption Exp. Square	-327.55 (209.21)	-188.67 (175.4)	-519.69 (458.86)	-162.79*** (58.26)
Land Owned* Collection Time	0.03 (0.04)	-0.03** (0.02)	-0.04 (0.04)	-0.03 (0.03)
Nonfarm Business Assets* Collection Time	-3.50 (2.86)	-1.13 (1.22)	-11.8* (6.59)	-0.77*** (0.23)
Cows Owned* Collection Time	0.01 (0.02)	0.03*** (0.01)	0.03* (0.01)	0.04*** (0.01)
Years Schooling of Head* Collection Time	-0.00 (0.02)	-0.03*** (0.01)	-0.03** (0.01)	-0.03*** 0.01
Household Size	-0.21 (0.55)	1.13*** (0.29)	0.32 (0.33)	1.26*** (0.26)
Household Size Square	0.03 (0.04)	-0.05** (0.02)	-0.01 (0.02)	-0.06*** (0.02)
Number of observations	478	1471	403	1095
*: significant at 10%, **: significant at 5%, ***: significant at 1%. The two first regressions include household age and sex structure variables. All regressions include a village fixed-effect. Standard errors in parentheses.				

Table 10: Conditional Engel curves: Trimmed LAD Estimates per Region

Dependent Variable: Fraction of Household Working Hours Allocated to Nonfarm Employment	
Value of Land Owned	-0.90 (0.98)
Nonfarm Business Assets	85.96** (43.17)
Number of Cows Owned	-2.23*** (0.43)
Years Schooling of Head	1.71*** (0.38)
Household Size	1.72 (1.37)
Household Size Square	-0.06 (0.10)
Literacy of Father of Head (dummy)	0.69 (2.78)
Father Self-employed Non-agric (dummy)	20.49*** (4.94)
Father Wage Labor Agri (dummy)	-1.84 (3.03)
Father Wage Labor Non-agri (dummy)	-0.65 (4.14)
Migrant for non-economic reasons (dummy)	3.66 (3.92)
Upper caste (dummy)	-2.81 (3.02)
*: significant at 10%, **: significant at 5%, ***: significant at 1%. All regressions include household age and sex structure variables.	

TABLE A1: Determinants of Nonfarm Employment

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



PERCENTILE MEAN DEVIATION OF FIREWOOD COLLECTION FROM THE VILLAGE MEAN
5
4
3
2
1
0
-1
-2
-3
-60000
-40000
-20000
0
20000
40000
60000
80000
dfirewood
Lower Bound
Upper Bound
PERCENTILE MEAN DEVIATION OF CONSUMPTION FROM THE VILLAGE MEAN

Figure2: InterVillage Firewood Collection-Consumption Plot

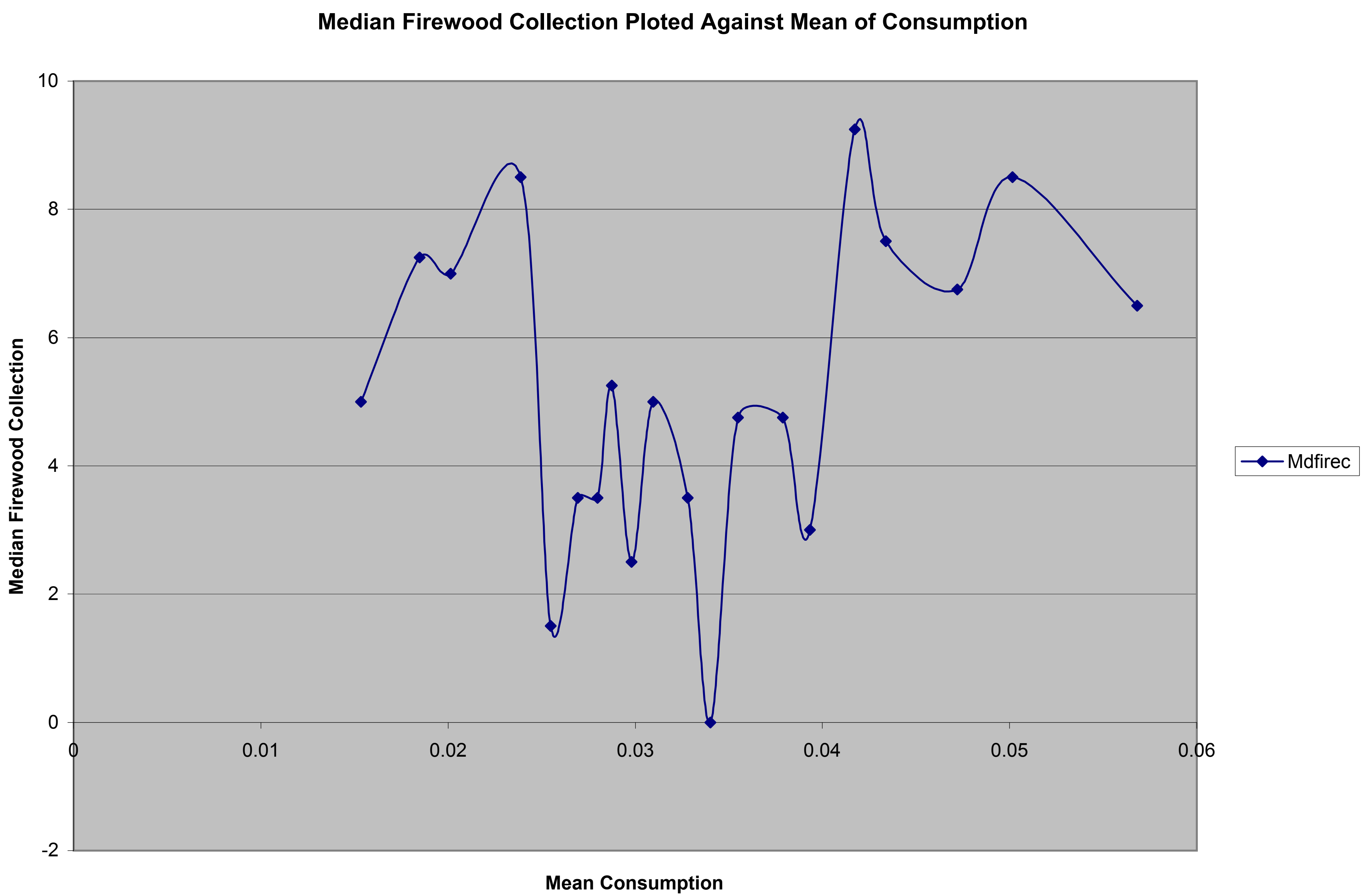
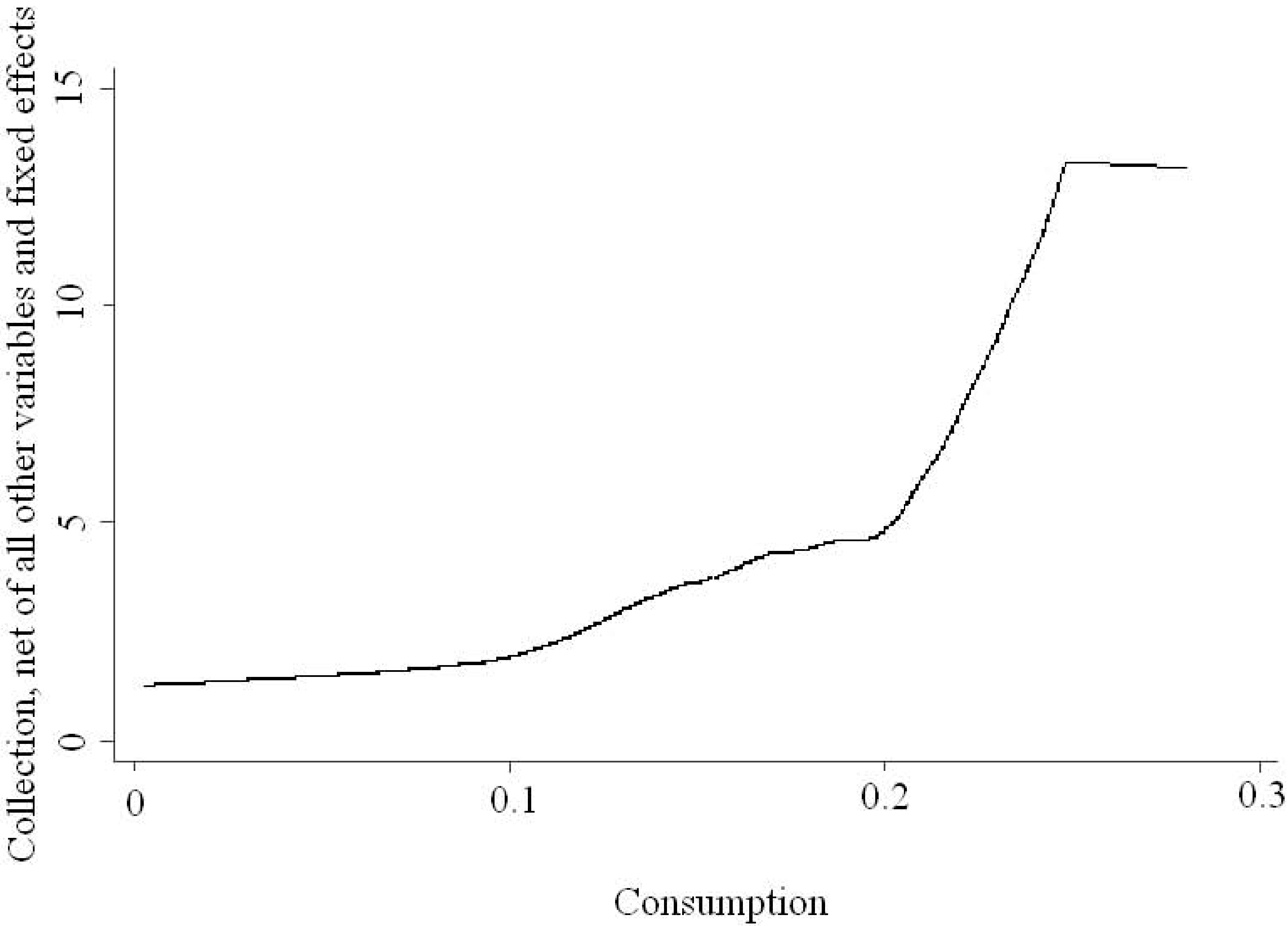

Median Firewood Collection Ploted Against Mean of Consumption
Median Firewood Collection
Mean Consumption
Mdfirec
10
8
6
4
2
0
-2
0
0.01
0.02
0.03
0.04
0.05
0.06

Figure 3: Non Parametric Relation between Collections and Consumption (basic model)



Collection, net of all other variables and fixed effects
15
10
5
0
0
0.1
0.2
0.3
Consumption