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Managing the Environmental Consequences of Growth: Forest Degradation in the Indian mid-Himalayas[1]

1. Introduction

The environmental consequences of growth is an actively debated issue, particularly in the current context of high growth performance in India and China [see, Arrow et al. (2006), Dasgupta *et al* (2000), Economy (2004),

1. Revised version of paper presented at the India Policy Forum 2006, at NCAER New Delhi. We thank Suman Bery, Devesh Kapur and Andy Foster for useful comments on the previous version. We are grateful to the Planning and Policy Research Unit of the Indian Statistical Institute, the Macarthur Foundation Network for Inequality and Economic Performance, and National Science Foundation Grant No SES-0079079 for funding this study. Thanks are due to Anil Sharma and Rakesh Sinha for excellent research assistance. We are deeply indebted to the team of field investigators—S. Parmar, Rajesh Kumar, Suresh Verma, Ramesh Badrel, Joginder Kainthla, Bhupesh Chauhan, P. Mohanasundaram, Sanjay Rana, Vidit Tyagi, Apurva Pant and Narendra Mandral—who bore great hardships and showed great commitment and courage during the process of data collection. We are deeply indebted to Dr Rajesh Thadani who designed and initiated the forest surveys and assisted us on ecology related issues. Thanks are also due to all the government officials at all levels in Himachal Pradesh and Uttaranchal who went out of their way to aid and assist us in conducting our field surveys. We would specifically like to thank Mr D. K. Sharma, Principal Secretary (Planning) Himachal Government, Dr Pankaj Khullar, Additional Principal Conservator of

Economist magazine (July 8, 2004),[2] McKibbin (2005)]. The 2006 Summit Report of the World Economic Forum, for instance, declared:[3]

> "China and India are at inflection points in their development requiring them to sustain economic development, in particular to manage natural resource consumption and environmental degradation."

A recent World Bank study of deforestation in India expressed significant concerns about the impact of population and economic growth:

> India's agricultural intensification has had a major positive impact, relieving pressure on marginal lands on which most of the forests remain. But urbanization, industrialization and income growth are putting a tremendous demand pressure on forests for products and services. The shrinking common property resource base, the rapidly increasing human and livestock population, and poverty are all responsible for the tremendous degradation pressure on the existing forest cover. (World Bank 2000, Summary section)

These assessments raise a number of important questions. Is there empirical evidence of substantial environmental degradation, and is it likely to be aggravated by growth? What is the likely impact of degradation on living standards, particularly of the poor? What is the nature of the externality involved; are local communities likely to resolve this via collective action and self-regulation? Or is it the case that there is need for external policy interventions? If so, what kind of policies should be considered; how effective are they likely to be?

There are a number of contrasting points of view among academics and policy makers concerning the environmental implications of growth. One is a pessimistic assessment, based on the notion that growth will raise the pressure on the earth's natural resources, for example, by raising the demand for energy, implying the need for policy measures to moderate and regulate environmental pressures. The viewpoint expressed at the World Economic Forum is representative of this. At the other extreme is a view (often labeled the Poverty-Environment-Hypothesis) that poverty is the root cause of environmental problems, implying that growth leading to poverty

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Forests, Himachal Forest Department, Dr R. S. Tolia, Principal Secretary, Uttaranchal Government. Finally, this survey would not have been feasible had it not been for the ardent and enthusiastic involvement of the local community inhabiting this region.

2. Economist, July 8 2004, "No Economic Fire Without Smoke," Books and Arts Section.

3. www.weforum.org/pdf/summitreports/am2006/emergence.htm.

reduction will solve environmental problems.[4] An intermediate hypothesis is that development may initially aggravate environmental problems, but once it passes a threshold it will subsequently ease them: often referred to as the 'Environmental Kuznets Curve'.[5] Yet another viewpoint stresses the importance of local institutions such as monitoring systems and community property rights.[6] It argues that deforestation in the past owed primarily to poor control and monitoring systems: once local communities are assigned control they will be successful in regulating environmental pressures, leaving no role for external policy interventions.

These hypotheses present different perspectives on the environmental consequences of development, and the role of policy. Yet there is remarkably little systematic micro-empirical evidence on their validity. Efforts to test these hypotheses have been cast mainly on the basis of macro cross-country regressions, with only a few recent efforts to use micro evidence concerning behavior of households and local institutions governing use of environmental resources [Chaudhuri and Pfaff (2003), Foster and Rosenzweig (2003), Somanathan, Prabhakar and Mehta (2005)].

This paper focuses on forests adjoining villages in the Indian mid-Himalayas (altitude between 1,800 and 3,000 metres), in the states of Himachal Pradesh and Uttaranchal. Pre-existing accounts of the state of these forests suggest a significant common property externality problem at both local and transnational levels. The local externality problem arises from the dependence of livelihood systems of local inhabitants on neighboring forests, with regard to collection of firewood (the principal source of household energy), fodder for livestock rearing, leaf-litter for generation of organic manure, timber for house construction, and collection of herbs and vegetables. Sustainability of the Himalayan forest stock also has significant implications for the overall ecological balance of the South Asian region. 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 or degradation aggravates the ravaging effects of regular earthquakes, and induces more landslides and floods. This affects the Ganges and Brahmaputra river basins, contributing to siltation and floods as far away as Bangladesh [see Myers (1986) and Metz (1991)].

4. Barbier (1997a, 1998, 1999), Duraiappah (1998), Jalal (1993), Lele (1991), Lopez (1998), Maler (1998).

5. Barbier (1997b), Grossman and Krueger (1995), Yandle, Vijayaraghavan and Bhattarai (2002).

6. Baland and Platteau (1996), Varughese (2000).

Our analysis is based on a range of household, community and ecology surveys of a sample of 165 villages divided equally between Himachal Pradesh and Uttaranchal, carried out by our field investigators between the years 2000–2003. Section 2 describes relevant economic and geographical characteristics of these villages pertaining to living standards and dependence on forests. Further survey details, and a detailed assessment of the state of the forests accessed by local villagers based on forest measurements, community interactions and anthropological surveys is provided in a companion paper [Baland et al (2006)]. Tree measurements in 619 adjoining forests accessed by villagers in our sample indicated that degradation (in the sense of declining tree quality) rather than deforestation (declining forest area or tree density) represented the predominant problem. Trees were severely lopped, forests exhibited low canopy cover and low rates of regeneration, mostly owing to firewood and fodder collection by neighboring villagers. Reported collection times for firewood increased over 60 percent during the past quarter century, amounting to approximately six additional hours per week per household. The extent of degradation was similar on average across state protected forests, community managed forests and unclassed forests. Vigilance mechanisms in state forests were widely reported to be ineffective. Only a small fraction of villages reported the existence of effective community management mechanisms. Households were aware of the deteriorating forest situation, yet the large majority reported absence of any significant local institutions or initiatives to arrest the process. This could not be explained by lack of knowledge of tree management practices (which are widely practiced on private trees and sacred groves), nor absence of social capital (as most villages have functioning local collectives for managing other local resources). These findings lend special urgency to the questions raised above concerning the likely impact of future growth and the need for corrective policy interventions in the Himalayan forests.

The absence of any significant forms of collective action among villagers concerning use of forests indicates that the major determinants of forest degradation are those that govern incentives of individual households to collect firewood and fodder from the forest, unconstrained by community norms or sanctions. Testing the Poverty-Environment hypothesis or the Environmental Kuznets Curve hypothesis then requires estimation of the income elasticity of demand for forest products, using conventional tools of demand analysis. In particular, these different hypotheses can be understood as presumptions concerning the nature of relevant wealth and substitution effects. The Poverty-Environment hypothesis is based on the notion that income increases generate negative wealth and substitution effects: households tend to switch to alternative fuels both because firewood is an inferior good and the shadow cost of time spent collecting firewood rises with household wealth. The Environmental Kuznets curve on the other hand could be generated if firewood is a normal good and the wealth effects dominate the substitution effects up to some wealth threshold, while substitution effects dominate past this threshold. Those expressing the view that growth will worsen the environment, focus attention primarily on positive wealth effects arising out of rising energy demands. Those arguing that growth and poverty reduction can improve the environment in contrast stress the importance of the negative substitution effects, apart from the possibility that firewood may be an inferior good.

Testing hypotheses concerning linkages between wealth and firewood collection and forming future projections of forest pressures thus requires us to estimate the related wealth and substitution effects. In our context, however, this raises a number of econometric difficulties. The chief problems concern potential endogeneity of income, as self-employment income constitutes the bulk of incomes earned by households in remote mid-Himalayan villages. For one, these depend on labor supply decisions of households in self-employment activities, which are jointly determined with firewood and fodder collection. One cannot therefore use actual income as an independent determinant of collection of forest products. Second, there may be many omitted variables that are not measured, which affect both incomes earned as well as firewood collected. Some of these may be unobserved household characteristics: for example, those with greater energy or better health may both earn higher incomes and collect more firewood, and the observed income-firewood correlation may reflect their joint dependence on these unobserved household traits rather than a causal link from income to firewood collection. Other omitted variables may be unobserved village characteristics, such as geography or climate that affect both incomes and forest stocks available. Third, firewood collection is a non-market activity, the cost of which from the standpoint of any household cannot be measured with reference to any market prices. The relevant 'price' of forest products is the value of time needed to collect them, which households will compare with the market price of alternative fuels. One needs to estimate the shadow value of time, on the basis of a model of intra-household allocation of time between self employed production tasks, household chores and leisure.

The approach we take to deal with these problems is as follows. In the short run, we take as given the size and structure of the household, the assets it owns, and its preferences for cooking and heating energy, consumption goods and leisure. We estimate a household production function which predicts self-employment income as a function of its asset composition, and use this to estimate the shadow value of time. This is subsequently used to impute a cost to the time spent collecting firewood. We also use the household production function to predict the income the household would have earned if it fully employed its available stock of labor for self-employment. This is a measure of 'potential income' which depends only on the assets owned by the household, and can be viewed as the relevant measure of wealth in the short run which does not depend on its labor allocation choices. Moreover, it is independent of unobserved household traits that may jointly affect labor supply and firewood collections. This measure of potential income is then used to estimate wealth and substitution effects, both with respect to household assets as well as cost of alternative fuels. We control for a variety of observed village characteristics (such as the composition of neighboring forests, village infrastructure and geography), and for unobserved village characteristics with fixed or random village effects. Section 3 describes the model and econometric methodology in more detail, and presents our estimates of household demand patterns.

The rest of the paper uses these estimated demand patterns to address the principal questions posed at the outset. Section 4 estimates the effects of future growth in household assets. For most households we find that the substitution and wealth effects neutralize each other: firewood and fodder collections turn out to be remarkably inelastic with respect to improvements in living standards. In particular we find no evidence in favor of the Poverty-Environment hypothesis, nor do we find any Kuznets-curve patterns. The effect of economic growth (that is, in assets or their productivity) *per se* is thus unlikely to increase the pressure on the mid-Himalayan forests, contrary to the assertions mentioned at the beginning of this paper.

In contrast, the effects of growth in population are likely to be adverse: rising population will cause a proportional rise in collections at the level of the village, while leaving per capita collections almost unchanged. To the extent that household division induces a shift to smaller household sizes, resulting loss of economies of scale within households will raise per capita collections even further. Hence anthropogenic pressures on forests are likely to be aggravated by demographic rather than economic growth. Unless there is substantial migration out of the mid-Himalayan villages, the pressure on forests is likely to grow substantially.

Section 5 estimates the effect of further forest degradation on the future livelihoods of neighboring villagers. These effects will be felt mainly in increased collection times. We have not attempted so far to estimate how collection of firewood and fodder at current levels will translate into forest degradation and increased collection times in the future. Instead we estimate the effects of increased collection times by one hour, which is a plausible estimate for the next decade or two, given the changes observed in collection time (one and half hour increase) over the past quarter century. The impact of this on livelihoods of neighboring residents turn out to be surprisingly low: the effect is less than 1 percent loss in household income, across the entire spectrum of households. Moreover, our model predicts no significant increases in time spent by children or male adults in collection, nor any increase in child labor. This indicates that the magnitude of the local externality involved in use of the forests is negligible, providing a possible explanation for lack of effort among local communities to conserve neighboring forests. The argument for external policy interventions then rests on the larger ecological effects of forest degradation. We are not qualified to assess the significance of these non-local externalities, while noting that these continue to be actively studied and debated among scientists and ecologists.

Should the ecological effects demand corrective action, Section 6 studies policy options available. The principal alternative to firewood is LPG among these households; kerosene and electricity only appear as secondary sources of fuel. Household firewood use exhibited considerable substitution with respect to the price and accessibility of LPG gas cylinders, suggesting the scope for LPG subsidies as a policy which could be used to induce households to reduce their dependence on forests for firewood. We estimate the effectiveness and cost of a Rs 100 and a Rs 200 subsidy for each gas cylinder. The latter is predicted to induce a rise in households using LPG from 7 percent to 78 percent, reduce firewood use by 44 percent, and cost Rs 1,20,000 per village annually (about 4 percent of annual consumption expenditure). A Rs 100 subsidy per cylinder would be half as effective in reducing wood consumption, but would entail a substantially lower fiscal cost (Rs 17,000 per village annually, approximately 0.5 percent of annual consumption).

The econometric estimates also show that firewood use is moderated when local forests are managed by the local community (van panchayats) in Uttaranchal. However, this effect is limited to those community managed forests that were judged by local villagers to be moderately or fairly effective, which constituted only half of all van panchayat forests. It is not clear how the government can induce local communities to take the initiative to organize themselves to manage the neighboring forests effectively, when they have not done so in the past. Moreover, even if all state protected forests could be converted to van panchayat forests, firewood use would be predicted to fall by 20 percent, comparable to what could be achieved with a Rs 100 subsidy per LPG cylinder. Hence policies aimed at increasing local community management of forests are likely to be less effective in curtailing firewood collection than subsidies on alternate fuels.

2. Survey Details and Descriptive Findings

Preceded by pilot surveys in representative villages, final surveys were done in 165 villages divided evenly between Himachal Pradesh and Uttaranchal over a period of three years 2000–03. A stratified random sample of 20 households in each village was selected, with villages selected on the basis of altitude, population and remoteness, and households on the basis of landholding and caste. Further details of the sampling design are provided in Baland et al (2006). All data reported here are based on our surveys, unless otherwise mentioned.

Figure 1 shows that average time taken to collect one bundle of firewood currently is 3.84 hours, as against 2.36 hours a quarter century ago.[7] The increased collection time reflects greater time taken within the forest to collect firewood, rather than shrinking forest areas: distance to the forest increased marginally from 2.06 to 2.31 kilometers. Time spent within the forest thus multiplied more than three times. This indicates that forest degradation rather than deforestation has been the main problem. Figure 2 shows that the amount of firewood used has dropped by 38 percent in the summer and 34 percent in winter over the past quarter century.[8]

Uttaranchal has a higher average standard of living compared with Himachal. Average household per capita annual consumption in Uttaranchal is Rs 9,300, and in Himachal is Rs 7,900 (all at prices at the time of the surveys); the poverty head count rates (using state-specific poverty lines) are

7. This data is from an ecology questionnaire based on interviews with 3 or 4 prominent village residents. The data concerning 25 years ago are based on recall by these respondents, with the exception of data on household size which we take from the Census. A bundle of firewood is the amount typically carried on the back of an adult, amounting to approximately 35 kg.

8. The econometric results of this paper provide the following explanation for this drop: increased collection times, rising levels of education and non-farm business, falling livestock ownership, and greater accessibility to alternate fuels such as LPG.

FIGURE 1. Change in Firewood Collection and Distance to Forest

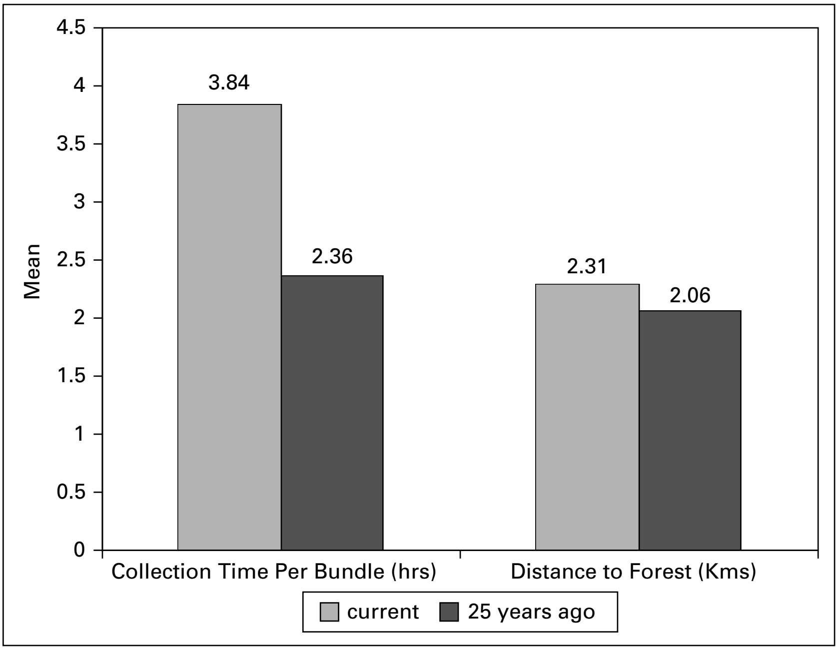
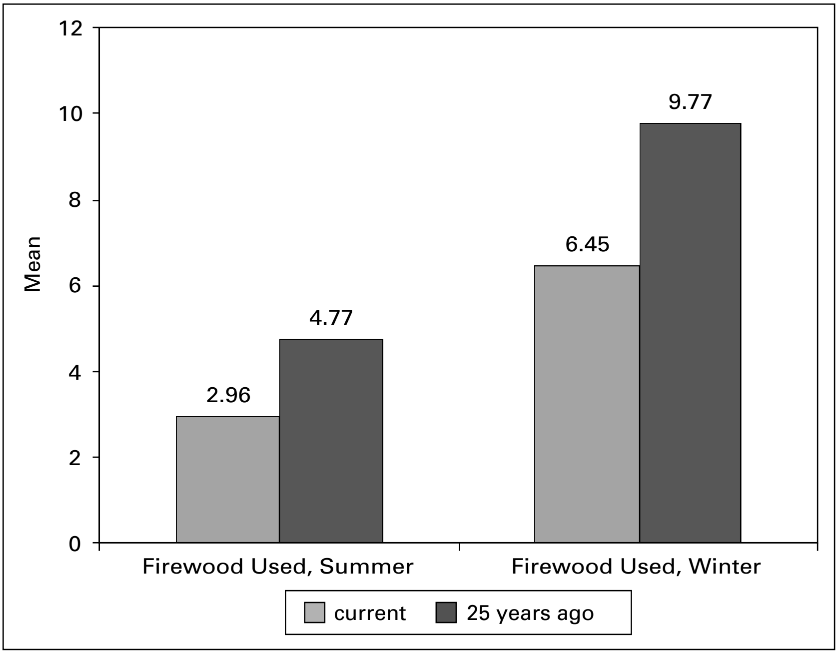


FIGURE 2. Change in Bundles of Firewood Used Per Week Per Family



4.8 percent and 24 percent respectively.[9] The average size of non-farm business per household is Rs 22,000 in Uttaranchal, double that of Himachal's. On the other hand, Uttaranchal households have fixed income (typically in the form of salaries and pensions) that is less than half of fixed incomes in Himachal. Levels of education are similar across the two states: total education in a household (that is, aggregating across all household adults) is approximately 13 years of schooling. Himachal villages have a higher average population of 545 people, compared with 334 for Uttaranchal. Finally, Himachal households collect more firewood—47 *bharis* on average per household member, compared with 40 in Uttaranchal. With an average household size of 5.6 in Uttaranchal and 5.8 in Himachal, this amounts to about 225 bharis for the household per year in the former and 270 in the latter. This translates into an annual collection time of approximately 750 hours in an average Uttaranchal household, and 900 hours in an average Himachal household.[10] Collection times are similar across the two states.

Figures 3–7 show changes in key village characteristics over the past quarter century. Roads have brought these villages much closer to the outside world, reducing distance to nearest road-link from 9.4 to 3.8 hours. Occupational patterns have moved away from reliance on agriculture and livestock, salaried employment has risen, and illiteracy rates have dropped considerably. Population has risen: the number of households per village doubled, while mean household size remained virtually the same.[11]

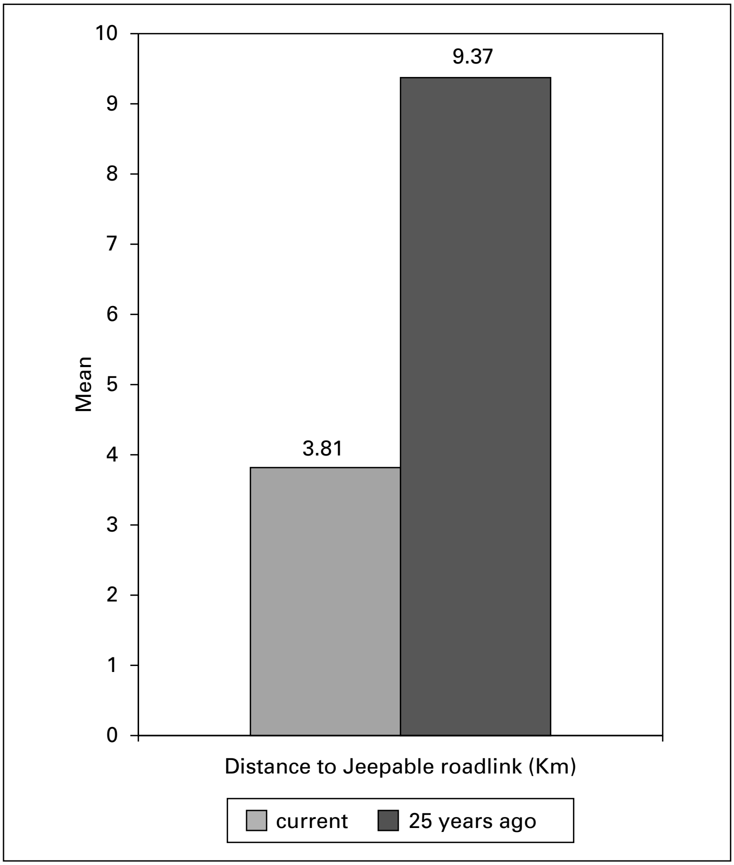
Figures 8–13 describe nature of fuel used by households in Himachal; we do not show the corresponding figures for Uttaranchal as they are very similar. Firewood is the principal source of cooking energy in the summer

9. Consumption was measured on the basis of a detailed questionnaire of household expenditure on different items, along the lines of a World Bank Living Standards Survey. Assets and fixed incomes are based on household responses to corresponding questions. Self-employment incomes are constructed on the basis of detailed questions concerning various inputs, outputs and prices of these in agricultural and livestock based activities. Potential income is constructed according to a method which is explained in the next section in some detail. This is an overstatement of the predicted permanent income of the household on the basis of various assets owned, owing to it being based on the assumption that the household utilizes all its available labor stock rather than at the observed utilization rates.

10. Collection times here are approximately 3.3 hours, the average of the times reported by the households in the sample. This is in contrast to the higher average collection time of 3.8 hours reported in the ecology questionnaire. Since the household questionnaire is based on a larger sample, we use these numbers from this point onwards.

11. Explaining these changes in village characteristics is outside the scope of this paper. A broader examination of growth effects on forests could conceivably encompass this, a task we leave for future research.

FIGURE 3. Change in Accessibility



for 90 percent households, followed by LPG which is used by 9 percent, and kerosene by the remaining 1 percent. Reliance on firewood becomes even more acute in the winter, when it becomes the primary source for both cooking and heat for over 99 percent households. LPG, charcoal and electricity are the primary source of the minority of remaining households. Kerosene and LPG appear as important secondary sources of cooking fuel, and electricity as a secondary source of heat energy.[12]

12. To avoid confusion, it is helpful to note that the figures concerning allocation of secondary fuel sources concern only the sub-population that reported using secondary fuels, whereas the figures concerning allocation of primary fuels applied to the entire population. Of the 1,636 households in Himachal, 543 used a secondary fuel and 111 used a tertiary fuel for cooking in summer where as 73 used a secondary fuel and only 1 household used a tertiary fuel.

FIGURE 4. Change in Occupation Structure of Household Head

FIGURE 5. Change in Livestock

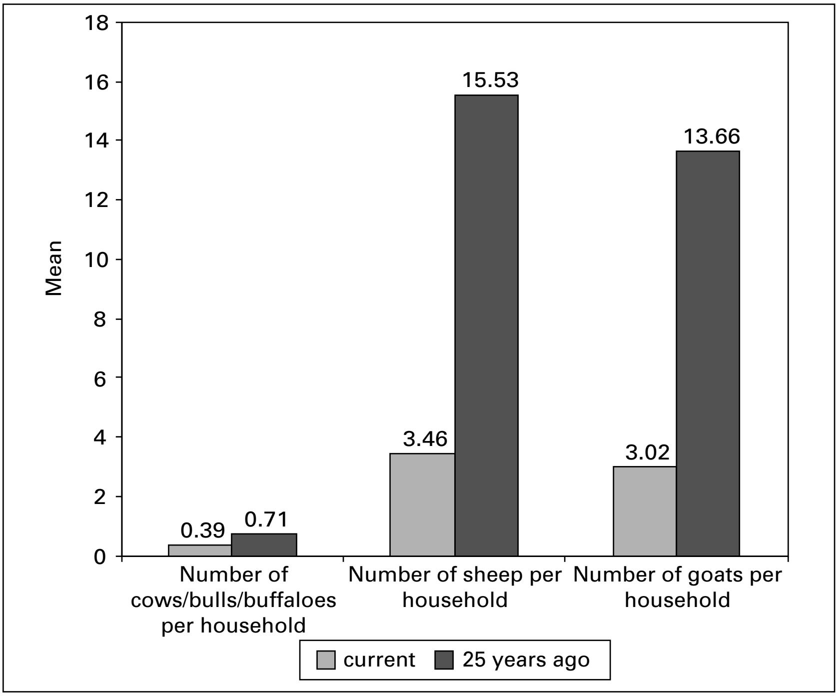


FIGURE 6. Change in Literacy of Household Heads

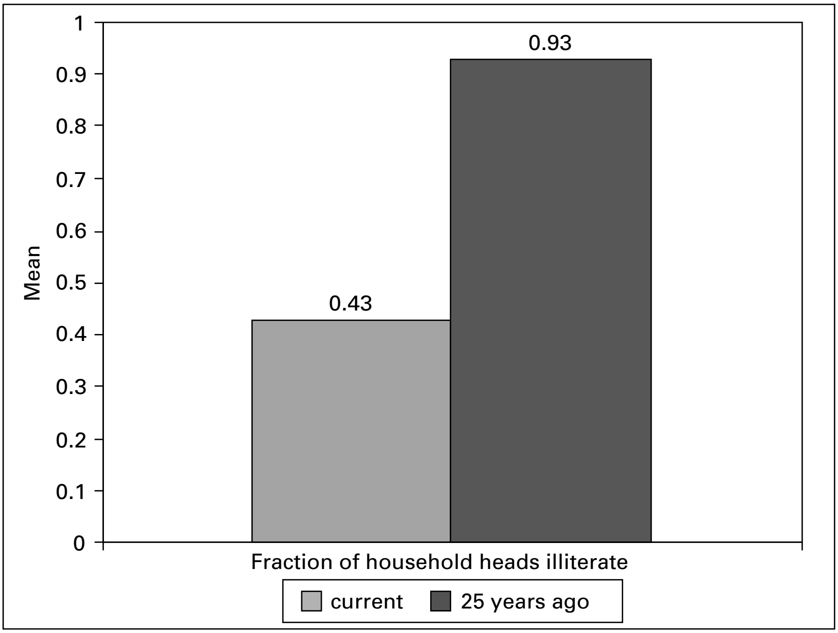


FIGURE 7. Change in Demographics (Source of Household Size 25 yrs Ago: Population Census of India)

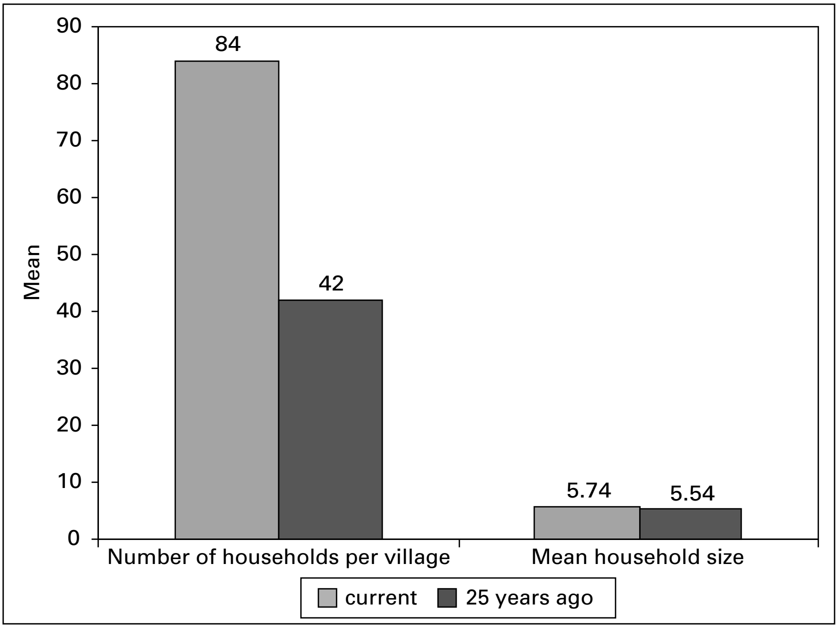


FIGURE 8. Primary Summer Cooking Fuel Source in Himachal Pradesh (Percent Households)

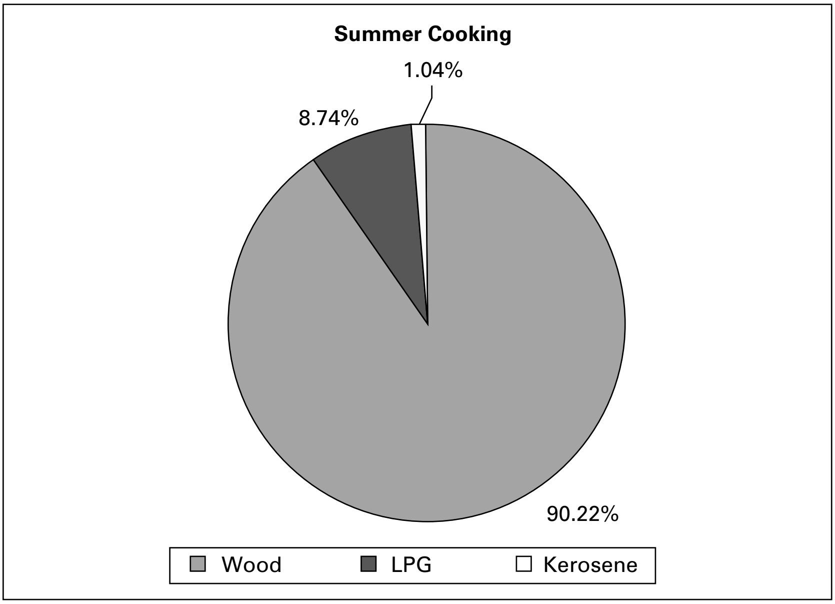


FIGURE 9. Primary Winter Cooking Fuel Source in Himachal Pradesh (Percent Households)

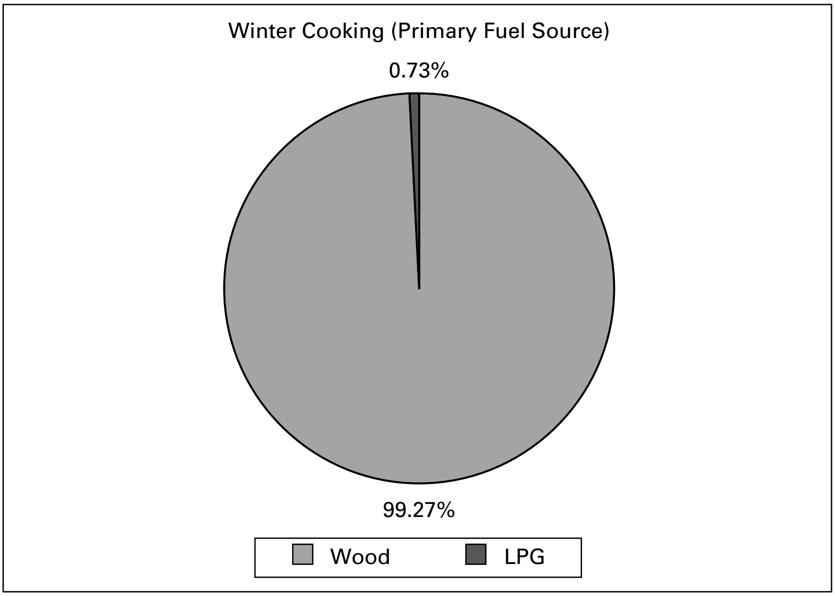


FIGURE 10. Primary Winter Heating Fuel Source in Himachal Pradesh (Percent Households)

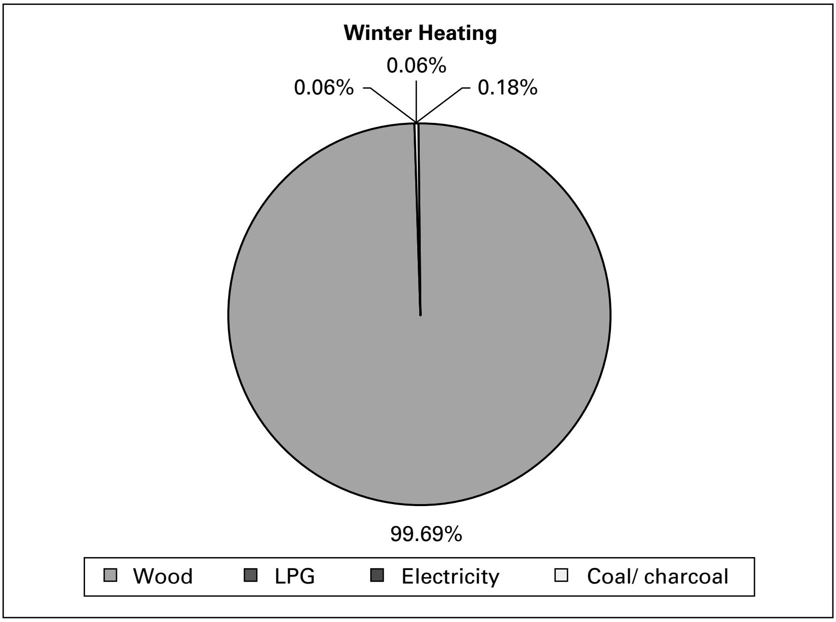


FIGURE 11. Breakdown of Secondary Fuel Source in Himachal Pradesh (Percent Households Reporting Use of Secondary Fuels)

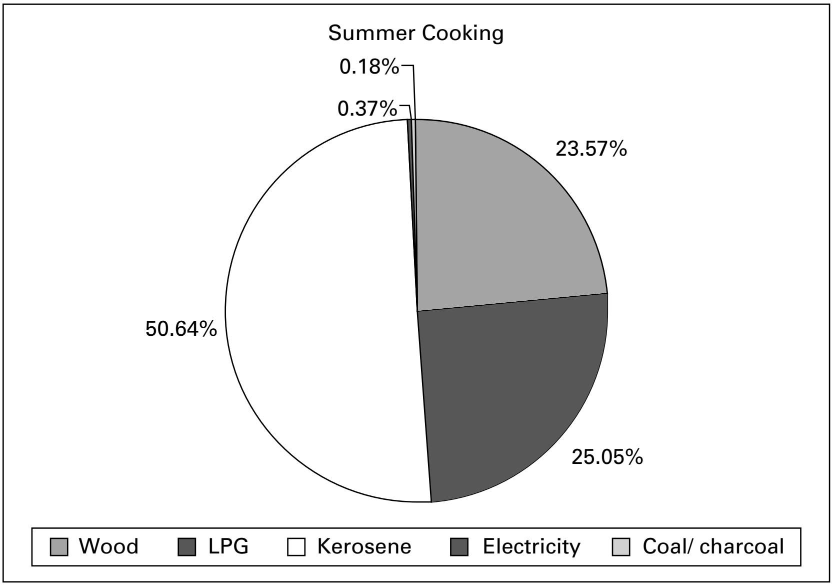


FIGURE 12. Breakdown of Secondary Fuel Source in Himachal Pradesh (Percent of Households Reporting Use of Secondary Fuels)

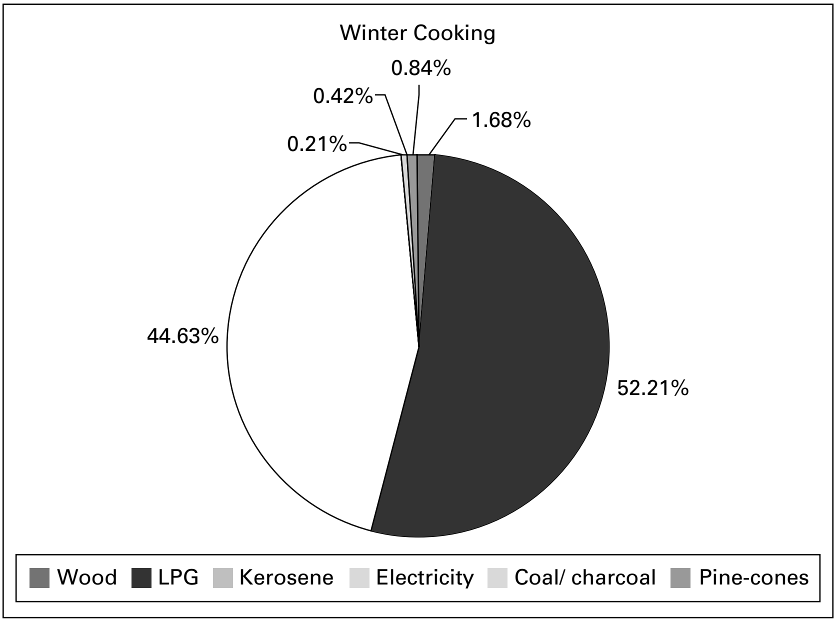
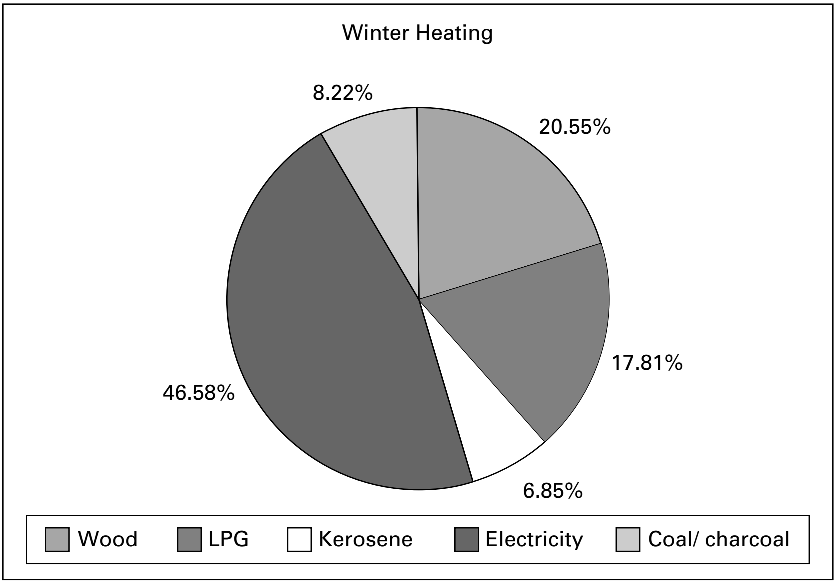


FIGURE 13. Breakdown of Secondary Fuel Source for Winter Heat in Himachal Pradesh (Percent of Households Reporting Use of Secondary Fuels)



The principal findings of our ecology and community interaction surveys were consistent with the above facts and are summarized as follows.

(a) The chief problem appears to lie in the degraded quality of forests, rather than deforestation. Measures of forest quality such as canopy cover, tree lopping and forest regeneration indicated severe degradation, with the problem being especially severe in Uttaranchal. 40 percent of all forest patches fell below sustainability thresholds used by ecology experts for canopy cover; in Uttaranchal the mean percent of trees severely lopped was exactly at the threshold of 50 percent. Tree stock density in comparison appeared quite healthy by comparison: only 15 percent of forest patches fell below the sustainability threshold of 35 square metres per hectare. Hence the nature of degradation does not involve a substantial reduction in forest biomass, and would not be picked up by aerial satellite images.
(b) Collection times for firewood have increased 60 percent over the past quarter century, while distance to the forest increased only 10 percent, another indicator of the importance of forest degradation rather than shrinking forest area. 60 percent of reported encroachment occurred with respect to village commons, as against only 5 percent with respect to forests.
(c) The main cause of forest degradation appears to be anthropogenic (collection of firewood, fodder and, timber) rather than natural causes (damage owing to fire or snow), with firewood and fodder collection predominating.[13]
(d) Over 80 percent of villages interviewed expressed awareness of deteriorating forest quality. Yet only 45 percent reported any sense of alarm within their communities. Most were aware of methods of sustainable tree management and practiced these on their private plots and on sacred groves. There was little or no evidence of informal collective action exhibited by local communities to arrest forest degradation, while there are numerous instances of collective action in other areas relevant to current livelihoods, such as agriculture and credit, besides women's groups, youth groups, temple committees etc.
(e) Measures of forest degradation do not vary between different categories of state or community forests. Monitoring of use of state forests appeared to be poor; collective plantation programs initiated by the forest departments have been ineffective.

13. Timber accounted for biomass removal of only 48 tons per village per year, compared with 456 tons per village per year for firewood.

(f) Formal community management of forests were largely ineffective in Himachal Pradesh. Half of the Uttaranchal villages had van panchayats (community managed forests), only half of which were perceived to be effective by local residents. Van panchayat forests exhibited the same extent of degradation as other forests.

(g) Anthropological studies in four villages corroborated the main findings of the ecology and community surveys: anthropogenic pressures are imposing a heavy toll on neighboring forests, and existing institutions of state or local community management appear to be largely ineffective to arrest this process.

3. Determinants of Household Firewood Collection

Given the findings reported above, it is necessary to study patterns in household behavior pertaining to their activities that affect sustainability of the forest stock. Since the primary source of degradation is lopping of trees for collection of firewood, we examine determinants of firewood use by households.

Theoretical Framework

The conceptual basis for this is a model of a household maximizing a utility function with five arguments:

$$U(C, E_h, E_c, \Lambda, n)$$

where C stands for consumption expenditures, E_h for heat energy, E_c for cooking energy, Λ for leisure and n for family size. Firewood is the sole source of heat, while LPG and firewood can both be used for cooking. Hence firewood has a joint product property: the exclusive dependence of households on firewood for heat in the winter months implies that all households will use firewood for cooking as well, with LPG used as a possible supplement. The inclusion of family size takes into account the fact that energy, and particularly heating energy, is to a large extent a public good within the household while consumption expenditures are not. Letting F stand for firewood and G for LPG, we have:

$$E_h = \phi F \text{ and } E_c = \omega F + \mu G$$

where (ϕ, ω, μ) represent the energy conversion coefficients.

Household income is the sum of fixed income (pensions, salaries of permanently employed members and wage employment earnings), denoted by I, and self-employment income, Y. The latter is in turn determined by the value of household production, given by a Cobb-Douglas production function of household labor supply, S, and the productive assets owned by the household: land N, big livestock, L_b, small livestock, L_s, education, E; and non-farm business assets, B:

$$Y = S^{\alpha_1} N^{\alpha_2} L_b^{\alpha_3} L_s^{\alpha_4} E^{\alpha_5} B^{\alpha_6} \tag{1}$$

Note that self-employment income Y is determined endogenously by the labor supply choices of the household, while fixed income I is exogenous. Hence it will not make sense to take self-employment income as a fixed household characteristic. However, household assets and demographics can be taken as given in the short run. To represent the household's wealth, it will thus be convenient to use as a proxy the following variable: *potential (self-employment) income* W defined to be the self-employment income that the household would earn if it were to fully utilize its labor stock available for self-employment activities.[14] Let T denote this labor stock, obtained by multiplying by 16 hours per day the number of adults (plus an adult equivalent scale of 0.25 for children) that are not engaged in salaried employment elsewhere, therefore available for household activities, productive self-employment and forest collection. Then potential income of the household is given by

$$W = T^{\alpha_1} N^{\alpha_2} L_b^{\alpha_3} L_s^{\alpha_4} E^{\alpha_5} B^{\alpha_6}$$

which by construction always exceeds the actual self-employment income. The main benefit of using this is that it is a function of household demographics and assets, and thereby independent of short run labor 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 labor used in self-employment is a decision variable. For instance, it is likely that more dynamic or better skilled farmers will simultaneously choose to

14. One reason why we separate fixed income and potential income is that access to a regular flow of income, such as provided by salaries or pensions may induce household to rely more extensively on LPG, by making liquidity available at regular time intervals, and reducing income risk. The other reason is that potential income can be treated as a proxy for the shadow wage, as explained further below.

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.

There is no market for firewood, so households collect firewood themselves.[15] As a result, the primary cost of firewood is the opportunity cost of time involved in collecting it. 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_f, also depends on the assets owned by the household. Since occupational choices are endogenously determined by labor allocation decisions within the household, we use as proxies the corresponding assets owned by the household that influence occupational choices. Letting t_c represent the time taken to collect firewood for a household with no assets, we assume:

$$t_f = t_c\,(1 + \gamma_1 N + \gamma_2 L_b + \gamma_3 L_s + \gamma_4 E + \gamma_5 B) \qquad (2)$$

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 big livestock reduces the time taken to collect firewood ($\gamma_2<0$) while running a non farm business increases it ($\gamma_5>0$). The cost of LPG is the price (including transportation cost) that must be paid for it, p_g. The budget constraint can then be written as:

$$C + p_g\, G = I + Y,$$

and the labor allocation constraint is given by:

$$T = S + \Lambda + t_f F,$$

where it may be recalled T represents the total amount of labor available for self employment.

15. See appendix table A-3: only 3 percent households in our sample purchase any firewood, and 0.1 percent do not collect any on their own. Even old people collect firewood: 2.68 percent of all collectors are above 65. There are 103 individuals of age 70 who collect; 12 at the age of 80; and 1 each from the ages of 86–93! Moreover, old people rarely stay alone: 0.2 percent of households have people only above the age of 65. In our field-work we were struck how even the most well-to-do households collected their own firewood rather than delegating it to servants or purchasing it from others.

The household maximizes utility by simultaneously choosing labor supply, firewood, LPG and consumption expenditures, taking assets, fixed income, demographics, the price of gas and the time taken to collect firewood as given in the short run. The resulting demand functions for firewood and for gas can be written as function of potential income, W, fixed income I, the shadow price of firewood (equal to the time t_f required to collect one bundle of firewood multiplied by the shadow value of time), the price of gas and household demographics (represented by household size, n, in adult equivalent consumption units).[16] The shadow value of time, w, corresponds to the marginal productivity of labor in self-employment occupations (determined in turn by the labor supply choice and household assets). We thus have:

$$F = F(W, I, w.t_f, p_g, n) \text{ and } G = G(W, I, w.t_f, p_g, n) \tag{3}$$

Taking a Taylor expansion, and allowing for higher order terms in income and demographics, we obtain the following equation that can be directly estimated:

$$\begin{aligned} F/n = {} & \beta_0 + \beta_1 W + \beta_2 W^2 + \beta_3 I + \beta_4\, w.t_f + \beta_5 p_g + \beta_6 n \\ & + \beta_7(1/n) + \beta_8 X_v + \varepsilon_{iv} \end{aligned} \tag{4}$$

and similarly for LPG, where X_v is a vector of village effects such as geography, type of local forest, proximity to towns, availability of alternate fuels etc.

A number of remarks on this formulation are in order. First, potential income as defined above provides a single measure of wealth which values and aggregates the different assets owned by the household. The second and third terms on the right-hand side of (4) 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 less smoky fuels such as LPG or electricity.

Second, the shadow value of time w also increases with potential income W, because the marginal productivity of self-employed labor is an increasing function of the assets owned by the household that are complementary

16. Household size in adult equivalent consumption units differs from labor stock T available for self-employment in two respects: it includes all adults in the household whether or not they are employed elsewhere, and it applies a weight of 0.5 rather than 0.25 to children.

to labor supply. Wealthier households therefore have a higher value of time, and a higher shadow price of using firewood. This implies that the substitution effects (represented by the fifth term in (4) above) also rise with W. 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. As explained in the Introduction, the difference between different viewpoints in the literature concerning the determinants of environmental degradation such as the Poverty-Environment hypothesis, the Kuznets curve can be interpreted as arising from different presumptions concerning the signs and significances of these wealth and substitution effects.

Third, if labor 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.[17] One problem with using the measured shadow wage as a determinant of the shadow price of firewood is that it depends on endogenous labor supply decisions of the household. We shall show below in our empirical estimates that shadow wages and potential income move closely together, controlling for household size. Therefore per capita potential income (that is, potential income W divided by T, the labor available for self-employment) can be used as a proxy of the shadow wage rate. Recalling the formulation of collection time t_f above as a function of household assets, the firewood demand equation can be written as a function entirely of household characteristics fixed in the short run:

$$\begin{aligned} F/n = {} & \beta_0 + \beta_1 W + \beta_2 W^2 + \beta_3 I + \beta_4 (W/T). \\ & t_c (1 + \gamma_1 N + \gamma_2 L_b + \gamma_3 L_s + \gamma_4 E + \gamma_5 B) \\ & + \beta_5 p_g + \beta_6 n + \beta_7 (1/\mathrm{n}) + \beta_8 X_v + \varepsilon_{iv} \end{aligned} \tag{5}$$

17. 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 (for example, 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 labor). Hence wage employment earnings were intramarginal, and the margin of labor-leisure choices operated solely with respect to home production.

Here the substitution effects appear as interactions between per capita potential income (W/T) of the household, average collection time in the village (proxied by t_c) and household asset stocks.

Empirical Results

The first step in the empirical analysis is estimating the household production function (1). Table 1 shows the estimated production function, with village fixed effects and labor hours instrumented by family size and composition.[18,19] The elasticity with respect to labor hours is 0.2, indicating that marginal products are one-fifths the size of average product of labor. Hence shadow wages are considerably below self-employment earnings per hour. Household income is particularly sensitive to ownership of land and big livestock (cows, bulls and buffalos), which have elasticities of 0.48 and 0.27 respectively.[20] The elasticity with respect to non-farm business assets is 0.08, and to schooling of adults is 0.06.

TABLE 1. Household Production Function

	Log self-employment income
Log Labor Hours#	.21***
	(.04)
Log Land	.48***
	(.03)
Log Non-farm Business Assets	.08***
	(.003)
Log Big Livestock	.27***
	(.03)
Log Small Livestock	.04***
	(.01)
Log education	.06***
	(.02)
No. Households	3291
No. Villages	165
Within-R sq.	.41

Notes: ***, **, * significant at 1 percent, 5 percent, 10 percent respectively, s.e. in parentheses.
Regression includes village fixed effects.
#: Instrumented with number of male and female adults in household

18. See Jacoby (1993) for a similar approach.

19. We use reported family labor hours in self-employed occupations, applying a weight of 0.25 to child labor hours. For instruments we use a number of adult males and females 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.

20. The definition of the asset variables used is provided in appendix table A-3.

The estimated production function is then used to calculate shadow wages and potential income. Recall that the shadow wage depends on assets of the household as well as labor supply decisions, and are thus endogenously determined. Table 2 shows the main determinants of shadow wages: potential income, household labor stock available for self-consumption, and occupational patterns (proxied by asset composition). A Gaussian kernel regression[21] between per capita potential income and shadow wage is shown in figure 14: the relationship is increasing, and approximately linear. Hence we can use per capita potential income as a proxy for the shadow wage in the firewood demand equation.

TABLE 2. Shadow Wage Regression

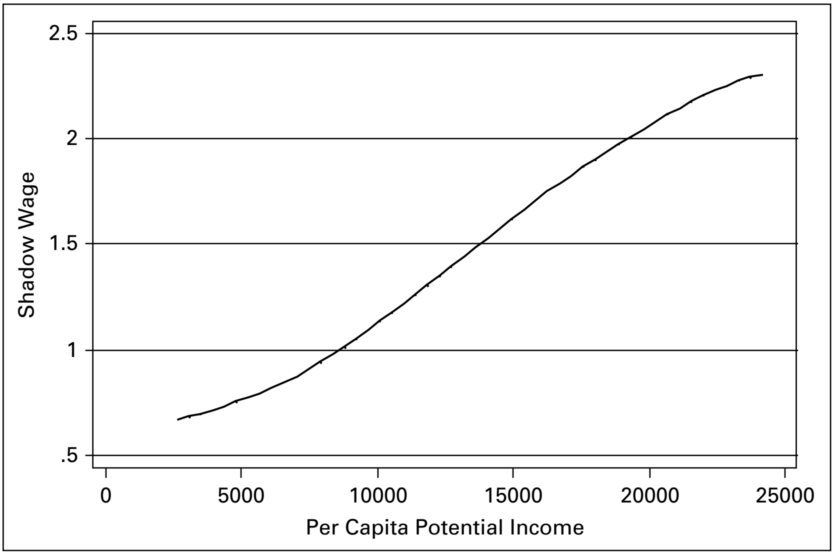
	Shadow wage
Potential Income	18E-6***
	(4.31E-7)
Potential Income Square	−6.16E-12***
	(3.97E-13)
Labor Stock	−.22***
	(.008)
Non-farm Business Assets	1.96E-6***
	(1.65E-7)
Land	.015***
	(.002)
Big Livestock	.003
	(.005)
Small Livestock	97E-6
	(5E-4)
Education	−.0016
	(.001)
No. Households	3272
No. Villages	165
Withjn-R sq.	.65

Notes: ***, **, * significant at 1 percent, 5 percent, 10 percent respectively, s.e. in parentheses. Regression includes village fixed effects.

Table 3 shows the estimated firewood demand equation corresponding to equation (4), where the shadow wage is used to measure the substitution effects. Table 4 shows the firewood demand corresponding to equation (5),

21. Kernel regression is a technique to relate the two variables in our case without imposing any functional form for the relationship. In short, it is a smoothed version of a scatter plot so that the nature of the relationship is easily observable; see Prakasa Rao (1983) for a survey of such techniques. We have used a Gaussian (normal) density function in the process and hence the name.

FIGURE 14. Per Capita Pot. Inc. & Shadow Wage



where per capita potential income is used as a proxy for the shadow wage. Since this uses exogenous household characteristics only as regressors, table 4 is the more reliable set of results, though we see that the results are very similar between tables 3 and 4. The first column of table 4 shows the estimates with village fixed effects, while the remaining columns (as well as table 3) include village characteristics and village random effects. The last two columns of table 4 show corresponding regressions for summer and winter use of firewood. The winter use can be interpreted as reflecting the joint effect of cooking and heating needs, while summer use reflects cooking needs alone.

Village characteristics include proportion of local forest area of different types that may be subject to different regulations concerning forest use: *van panchayat*s, sanctuaries, and un-classed state forests, with state protected forests (DPFs and RFs) being the control category.[22] Others are the price of LPG cylinders (plus transport cost to the doorstep of the household), a dummy for irregular availability of LPG as reported by households, altitude,

22. *Van panchayat*s are forests owned and managed by the local community, which arise only in Uttaranchal. Remaining forests are mainly state forests, of which some are sanctuaries (where households have no collection rights at all), demarcated protected forests (DPF) and reserved forests (RF) in which households have restricted collection rights, the remainder being unclassed or undemarcated state forests where there are no restrictions on their collection rights. For further details see Baland et al (2006).

TABLE 3. Per Capita Firewood Use with Shadow Wage

	Random effect
Potential Income	5.62E-05***
	(1.57E-05)
Potential Income Sq	–1.36E-11
	(2.11E-11)
Fixed Income	2.02E-06
	(7.19E-06)
Firewood Collection Time * Shadow Wage	–0.89***
	(0.17)
Firewood Collection Time * Shadow Wage*Big Livestock	0.052***
	(0.02)
Firewood Collection Time * Shadow Wage*Small Livestock	.001
	(0.002)
Firewood Collection Time * Shadow Wage*Non-Farm Business Assets	3.02E-08
	(1.68E-07)
Firewood Collection Time * Shadow Wage*Education	–0.01**
	(0.004)
Firewood Collection Time * Shadow Wage*Land	–0.001**
	(0.005)
1/Household Size	109.69***
	(4.85)
Household Size	–0.88***
	(0.26)
% Forest Area Van Panchayat	–0.07***
	(0.03)
% Forest Area Sanctuary	0.03
	(0.04)
% Forest Area Other Excluding DPF	0.048**
	(0.02)
Population	0.004*
	(0.002)
LPG Price	0.08***
	(0.03)
LPG Irregular Availability Dummy	1.70
	(1.47)
Altitude	0.005**
	(0.002)
Firewood Collection Time	–3.81**
	(1.28)
No. Households, Villages, within-R sq.	3268,165,0.36

average collection time in the village, and a number of measures of climate, infrastructure, remoteness, village population, land inequality, ethnic fragmentation which may affect energy preferences or local collective action to regulate forest use.

TABLE 4. Reduced Form Regression of Per Capita Household Firewood Use

	Village fixed effect-all year	*Random effect†-all year*	*Random effect-summer*	*Random effect-winter*
Potential Income	5.01E-05***	4.05E-05**	3.14E-05**	9.07E-06
	(1.81E-05)	(1.78E-05)	(1.35E-05)	(8.67E-06)
Potential Income Sq.	1.57E-11	2.41E-11	3.00E-12	2.14E-11**
	(2.09E-11)	(2.03E-11)	(1.54E-11)	(9.89E-12)
Fixed Income	7.32E-07	−6.55E-07	−1.46E-07	−6.08E-07
	(7.25E-06)	(7.22E-06)	(5.47E-06)	(3.53E-06)
Firewood Collection Time*PCPotential Income	−5.24E-05***	−4.56E-05***	−3.64E-05***	−8.48E-06
	(2.00E-05)	(1.74E-05)	(1.33E-05)	(8.22E-06)
Fw. Collection Time*PCPotential Income*Big Livestock	4.01E-06**	4.33E-06**	3.15E-06**	1.20E-06
	(1.79E-06)	(1.72E-06)	(1.31E-06)	(8.33E-07)
Fw. Collection Time*PCPotential Income*Small Livestock	9.43E-08	1.54E-07	1.87E-07	−3.52E-08
	(2.85E-07)	(2.84E-07)	(2.15E-07)	(1.39E-07)
Fw. Collection Time*PCPotential Income*Nonfarm Business Assets	−2.36E-11*	−2.45E-11*	−1.13E-11	−1.33E-11*
	(1.40E-11)	(1.39E-11)	(1.05E-11)	(6.78E-12)
Fw. Collection Time*PCPotential Income* education	−1.24E-06***	−1.35E-06***	−5.46E-07	−8.22E-07***
	(4.72E-07)	(4.69E-07)	(3.55E-07)	(2.29E-07)
Fw. Collection Time* PCPotential Income*Land	−6.63E-07	−7.43E-07	−5.46E-07	−2.15E-07
	(5.07E-07)	(4.74E-07)	(3.61E-07)	(2.29E-07)
1/Household Size	104.33***	104.06***	46.14***	58.01***
	(4.81)	(4.79)	(3.63)	(2.34)
Household Size	−1.01***	−9.38E-01***	−6.60E-01***	−2.67E-01**
	(0.26)	(2.62E-01)	(1.99E-01)	(1.28E-01)
Fw Collection Time		−4.24***	−2.90***	−1.35**
		(1.29)	(1.05)	(5.41E-01)

(Table 4 continued)

(Table 4 continued)

	Village fixed effect-all year	*Random effect†-all year*	*Random effect-summer*	*Random effect-winter*
LPG price		8.05E-02***	4.79E-02**	3.26E-02***
		(2.87E-02)	(2.34E-02)	(1.21E-02)
LPG Irregular Availability Dummy		1.84	1.35	4.96E-01
		(1.48)	(1.21)	(6.21E-01)
% forest area van panchayat		–8.05E-02***	–5.45E-02***	–2.63E-02**
		(2.52E-02)	(2.06E-02)	(1.06E-02)
% forest area sanctuary		2.98E-02	–4.68E-03	3.42E-02**
		(3.64E-02)	(2.98E-02)	(1.53E-02)
% forest area other excluding DPF		4.88E-02**	9.20E-03	3.96E-02***
		(2.31E-02)	(1.89E-02)	(9.70E-03)
Altitude		5.21E-03**	2.89E-03	2.36E-03**
		(2.24E-03)	(1.77E-03)	(1.01E-03)
Population		3.68E-03*	1.33E-03	2.36E-03***
		(1.94E-03)	(1.59E-03)	(8.15E-04)
No. Households, Villages, within-R sq.	3288,165,.35	3284,165,.35	3284,165,0.17	3284,165,0.39

Note: ***, **, * significant at 1 percent, 5 percent, 10 percent respectively, s.e. in parentheses.

† Random effect regression additionally includes the following village characteristics whose coefficients are not reported here—time to jeepable road, time to block office, ethnic fragmentation, gini of land, snowfall and whether a village had electricity connection. All of these turned out to be statistically insignificant.

For the sake of brevity, we focus mainly on the firewood use regressions, though we have estimated analogous fodder collection regressions as well, which are shown in the appendix. Firewood and fodder collection are highly complementary activities, often accomplished on the same trip to the forest. So it is not surprising that fodder and firewood regressions exhibit similar properties, justifying our focus on firewood use in the main body of the paper.

The results of the fixed and random effects wood use regressions in table 4 are very similar, lending confidence to the random effects specification (which is based on the assumption that omitted village characteristics are uncorrelated with included characteristics). Village characteristics included (apart from the ones reported in the table) are time to roads, government block office, ethnic fragmentation, land inequality, snowfall, and an electrification dummy; all of these were statistically insignificant. A larger set of village characteristics pertaining to geography and infrastructure altered the reported coefficients very little. We therefore report the more parsimonious specification in table 4.

The regression results show wealth effects are positive and significant, while a number of substitution effects are negative and significant, with one exception. Since firewood collection and grazing of livestock are complementary activities, the substitution effect is positive with respect to ownership of big livestock. On the other hand, education, ownership of non-farm business assets and land are associated with non-livestock occupations; time spent in such occupations and in collection of firewood or fodder are substitutes. This explains why the estimated substitution effects with respect to ownership of non-livestock assets are negative.

There is evidence of household economies of scale: larger households use less firewood per capita.[23] Firewood use is sensitive to the cost of LPG, and not so much to whether it is available regularly. Proximity to van panchayat forests is associated with less use of wood compared with state DPF forests, while unclassed forests involve higher use of wood. This suggests that monitoring by state or community appointed forest guards are effective to some extent, and community monitoring more effective than state monitoring. Higher village population is associated with slightly higher use of wood, owing possibly to a dilution of enforcement or monitoring in larger villages.

23. A decrease in household size by one adult (resp. one child) in an average household (i.e., with characteristics equal to the average characteristics in the sample) is estimated to raise firewood use per capita by 10.6 percent (resp. 5.2 percent).

The regression for fodder in appendix table A-1 additionally includes number of big and small livestock owned (in addition to their interaction with the shadow cost of firewood collection time). Here wealth effects are negative, and the substitution effect is positive with respect to ownership of small livestock. LPG use does not affect fodder collected, nor does the presence of van panchayat forests. In other respects fodder collection is similar to firewood use.

4. Effects of Growth

The estimated patterns of firewood collection yield predictions for effects of future growth in incomes, assets and population. The underlying assumption is that cross-sectional variations in firewood collection across households at a point of time can be used to predict how behavior of any given household will respond when its circumstances change over time. Temporal responses are typically smaller compared with what cross-sectional long run elasticities predict: for example, because households may treat part of the increased incomes as transitory, or may take time to adjust their habits. However, short and long run responses tend to move in the same direction. As we shall argue, this consideration will further strengthen our main findings below.

An additional problem is that the estimated income elasticities may be biased owing to omission of unobserved household attributes that affect both their assets and firewood collection. For instance more farsighted, energetic, better located, or better connected households may both accumulate more assets and collect more wood. The estimated elasticities from the cross-sectional variations across different households will then overstate the extent to which wood collection will increase following asset increases of any given household. Again, this will turn out to strengthen our principal conclusions below.

Tables 5 and 6 show the impacts on per capita firewood use of: (i) a 10 percent increase in each relevant asset and (ii) a 10 percent change in potential income owing to an increase in productivity of assets while asset compositions remain unchanged. Table 5 shows the effect on an 'average household', defined to be a hypothetical household with average characteristics (that is, each characteristic is set equal to the corresponding average in the sample). It shows that firewood use is inelastic with respect to income growth, irrespective of whether it arises from productivity increases

TABLE 5. Effects of 10 percent Growth on Yearly Per Capita Firewood Use of Average Household

Variables	*% change*
Increase in Land by 10 percent	–0.08
Increase in Big Livestock by 10 percent	0.15
Increase in Small Livestock by 10 percent	0.01
Increase in Education by 10 percent	–0.19
Increase in Non-Farm Business Assets by 10 percent	–0.01
Increase in Productivity of Assets by 10 percent	–0.06

TABLE 6. Impact of 10 percent Growth on Yearly Per Capita Firewood Use of All Households

Potential income PI	*Variable*	*Obs*	*Mean*
Overall	Land	3283	–0.14
	Big Livestock	3283	0.21
	Small Livestock	3283	0.01
	Education	3283	–0.32
	Non-Farm Business Assets	3283	–0.05
	Increase in Productivity of Assets	3279	–0.08
First Quartile	Land	822	–0.05
(PI < 22059.54)	Big Livestock	822	0.04
	Small Livestock	822	0.0002
	Education	822	–0.06
	Non-Farm Business Assets	822	–0.01
	Increase in Productivity of Assets	819	–0.07
Second Quartile	Land	820	–0.08
(PI >= 22059.54	Big Livestock	820	0.09
and < 34213.83)	Small Livestock	820	0.01
	Education	820	–0.13
	Non-Farm Business Assets	820	–0.01
	Increase in Productivity of Assets	820	–0.08
Third Quartile	Land	820	–0.10
(PI >= 34213.83	Big Livestock	820	0.16
and < 55737.3)	Small Livestock	820	0.01
	Education	820	–0.21
	Non-Farm Business Assets	820	–0.01
	Increase in Productivity of Assets	819	–0.08
Fourth Quartile	Land	821	–0.33
(PI >= 55737.3)	Big Livestock	821	0.55
	Small Livestock	821	0.02
	Education	821	–0.89
	Non-Farm Business Assets	821	–0.17
	Increase in Productivity of Assets	821	–0.09

or asset accumulation. For the average household, firewood use per capita falls 0.06 percent following an increase in asset productivity of 10 percent. The elasticity with respect to growth of any asset is uniformly below 0.02 in absolute value.

Table 6 shows the average of the predicted impacts across households, evaluated at their observed characteristics, and broken down into different quartiles. The elasticity with respect to increased asset productivity is less than .009 in absolute value for all groups. With respect to growth in big livestock the average elasticity is .02, and is –.03 with respect to growth in years of schooling. These elasticities get larger for the richest households (upper-most quartile) for whom they are only .05 and –.09 respectively. Hence firewood use is essentially inelastic with respect to growth in incomes or assets. If temporal elasticities are smaller than cross-sectional elasticities, the inelasticity is further reinforced.

Appendix table A-2 shows similar results for fodder. These findings are consistent with anthropological studies in selected villages (reported in our companion paper (Baland et al. (2006)), in which villagers claimed that everyone in the village uses the same amount of firewood irrespective of their circumstances. We therefore do not find support for any of the viewpoints on the connection between growth and the environment: differences in living standards have no discernible impact on firewood or fodder collection.

Why does firewood use exhibit this inelasticity? This is a natural question to ask since firewood is virtually the sole source of heat energy, the demand for which one would have expected to rise with income. And the firewood collection equation does exhibit sizeable and positive wealth effects. The answer lies in the fact that rising potential income also raises the shadow wage, thus raising the substitution effects, which offset the wealth effect. Firewood is becoming more expensive at the same time that wealth is increasing, so households are switching to alternate forms of energy as they become richer (which will be verified below for LPG in Section 6).

Note that the inference that economic growth *per se* is unlikely to increase the pressure on forests is further reinforced if we take account of short run adjustment costs or possible biases arising from omission of unobserved household traits in the firewood regression, since these are likely to have resulted in overestimation of the effect of increased wealth on collections.

Next consider the effects of population growth. The average household size of 5.7 indicates that most families are nuclear already and there is little scope for further fragmentation of households. Recall also from Section 2 that household size has not changed much over the past quarter century. Moreover, within villages we find little variation in household size with per capita potential income.[24] So it is reasonable to assume that household size will remain fixed in the near future, irrespective of economic growth. This implies that population growth will consist mainly of an increase in the number of households. Unless there is substantial out-migration from villages, it is reasonable to suppose that population will grow by at least 10 percent in the next decade. If the number of households in the village were to grow by 10 percent, the demand for firewood and fodder will correspondingly rise by approximately 10 percent.[25] If households become more fragmented, the loss of household scale economies will further reinforce this.

We therefore conclude that demographic changes rather than economic growth will determine future growth in household use of firewood and fodder. In the absence of significant increases in migration out of these villages, the pressure on forests will rise approximately in proportion to the rise in population, that is, of the order of 10 percent or more in the next decade, resulting in further forest degradation.

5. Quantifying the Local Externality: Impact of Deforestation on Local Living Standards

Continued forest degradation will impact the lives of neighboring villagers primarily by raising the time it takes them to collect firewood and fodder. If trees are more severely lopped, the villagers will take longer to collect a single bundle, either by searching longer for trees that still have branches that can be lopped, or walking further into the forest parts that have not yet been harvested. This is the principal source of the local externality: higher

24. The average number of adults across quartiles of per capita potential income are 3.50, 3.63, 3.44, and 3.37 respectively, with a standard deviation of approximately 1.4. The average number of children are 1.49, 1.71, 1.54, and 1.38; the standard deviation is approximately 1.4. Hence these differences are not statistically significant.

25. Recall that table 4 showed that rising population in the village tends to have a negligible (positive) impact on per capita household use of firewood. A 10 percent rise in village population would correspond to a population increase of approximately 40, which table 4 shows will raise per capita annual firewood use by .015 bundles, compared to the current average of 45 bundles. Hence the effect on per capita use would be negligible, implying that the effects of population growth will be approximately proportional to the rise in population.

collections today by any single household will raise collection times for all households in surrounding villages in the future.

Precise quantification of the magnitude of this local externality requires knowledge of the rate at which future collection times will rise in response to current collection levels.[26] We have not attempted to estimate this so far. Instead we will try to provide some bounds for the magnitude of the externality, on the basis of certain simplifying assumptions. In the past quarter century collection times have risen by one and a half hours per bundle, while collection levels have fallen. *Assuming that the relation between collection levels and the subsequent rise in collection time observed in the past will continue into the future,* one would expect the future rise in collection times to be lower than has been observed in the past. Since population growth rates are slowing, and economic growth is unlikely to matter in determining collections, the rate of growth in collection can be expected to be slower than observed in the past. If the relationship between growth in collection and changes in collection times are linear, one can project on the basis of past trends.

The justification for this is that there do not appear to be any noticeable thresholds in forest degradation in the areas covered in this study: In most of the forest areas concerned, villagers have traditionally accessed a small fraction of the overall forest area adjoining their villages, with vast portions of the forest yet to be actively tapped. As the areas close to the villages become more degraded, households can simply walk deeper into the forest to find un-lopped trees. Therefore the prospect of sudden increases in collection times disproportionate to those observed historically seems to us fairly remote, though of course further scientific opinion needs to be sought on this matter.

We shall therefore consider the effects of an increase in collection time by one hour per bundle; under the assumption mentioned above, this seems a reasonable upper bound for the increased collection time that may be expected for the next decade or two. It will turn out that the results will hardly change if we double the estimated rise in collection time from one to two hours per bundle.

Applying Hotelling's Lemma, the effect of a small increase in collection time on household welfare can be approximated simply by calculating the shadow cost of additional time required to collect the same number of bundles of firewood selected by the household prior to the increase in

26. We thank Andy Foster for pointing out the need for this information in order to estimate the magnitude of the externality.

collection time. For large changes in collection time, this provides an upper bound to the welfare loss of the household, since the household can adjust its collection levels as the collection time rises. Indeed, as we saw in table 4, households do indeed reduce collections considerably as collection times rise, implying that the actual welfare loss is smaller than this upper bound. We compute this upper bound by using the estimated shadow wage to value the added collection times that would be involved in collecting the same amount of firewood as today.[27]

A simple back-of-the-envelope calculation indicates that the mean effect of an increase in collection time by one hour per bundle is extraordinarily small. The average shadow wage is Rs 1.5 per hour, and mean firewood collected by a household is 181 bundles per year. Given a per household consumption of Rs 38,200 per year, this translates into an average drop of 0.81 percent in annual consumption.

Could it be the case that this average effect conceals large distributional effects? How would the costs vary across poor and rich households? The distributional impact is not *a priori* obvious. On the one hand, the poor have a lower shadow wage. So the *total* impact on the poor will be lower. On the other hand, their consumptions are also lower, so the *proportional* effect is not clear. Since firewood use is inelastic with respect to wealth increases, the poor will rely proportionately more on firewood, though less in absolute terms. This suggests that the poor will be more adversely affected. On the other hand, their shadow wage is lower, so the overall proportional effect is unclear.

For each household we compute the proportional income loss by multiplying the shadow wage with the increased collection time associated with the same level of collections, and then express this as a proportion of their estimated permanent income (the predicted income from the household production function, using their current labor supply). Figure 15 shows a nonparametric (Gaussian kernel) regression of estimated proportional income loss against per capita potential income. The loss is higher for the poor: the loss is decreasing monotonically with respect to income (except at the very top end). But even for the poorest, the loss is less than 1 percent. Table 7 controls for other characteristics presents the parametric regression of estimated proportional income loss against household potential

27. Households could not distinguish between times spent collecting fodder and firewood, consistent with our view that these activities are highly complementary, often accomplished in the same visit to the forest. Hence there is no need to separately add effects on time spent collecting fodder. We also found negligible effects on incomes collecting vegetables and medicinal herbs, so we have neglected this in the discussion below.

FIGURE 15. Per Capita Pot. Inc. & Degradation Impact

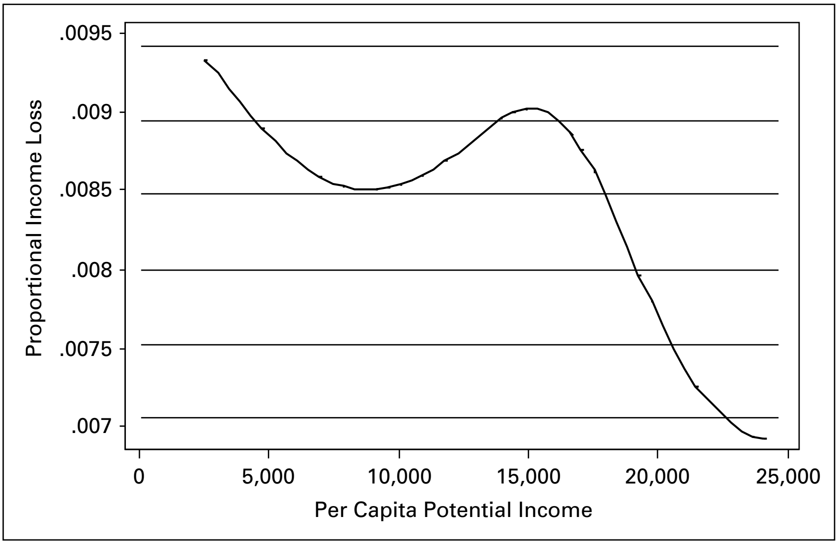


TABLE 7. Proportional Income Loss Owing to Increase in Firewood Collection Time by One Hour

	Proportional income loss
Constant	0.01***
	(0.0005)
Potential Income	3.07E-08***
	(8.18E-09)
Potential Income Square	–3.11E-16
	(7.77E-15)
Labor Stock	–0.0003**
	(0.0002)
Non-farm Business Assets	–2.13E-08***
	(3.04E-09)
Land	–9.31E-05**
	(3.84E-05)
Big Livestock	–3.4E-04***
	(1.01E-04)
Small Livestock	–1.28E-05
	(9.20E-06)
Education	–1.12E-04***
	(1.92E-05)
No. Households	3272
No. Villages	165
Withjn-R sq.	0.05

Note: ***, **, * significant at 1 percent, 5 percent, 10 percent respectively, s.e. in parentheses. Regression includes village fixed effects income. Both regressions show that the loss is bounded above by 1 percent. If collection times rose by two hours instead of one hour, the welfare loss would be bounded above by 2 percent of current consumption.

The magnitude of the local externality on living standards is thus remarkably small, assuming that current collection activities give rise to increases in future collection times on a scale similar to those observed in the past. In any case, it is unlikely that households in neighboring villages would expect future increases in collection times to be substantially larger than what they have observed in the past quarter century. Hence the local externality *perceived* by villagers is likely to be very small. This provides a possible explanation for the absence of any significant collective action or concern among villagers to conserve forest use.

What about the impact on other dimensions of household living standards, such as leisure, child labor or gender allocation of household tasks? How exactly are households likely to adapt to higher collection times? Tables 8 and 9 show the effects on firewood use and on total time spent collecting. Wood use declines by 14 percent, averaging across all households; the cutback tends to rise with wealth: for the bottom (rep.) top quartile it falls by 10 percent (resp. 19 percent). This reduction is less than the increase in collection time per bundle, implying that total time spent

TABLE 8. Effect of an Increase of One Hour in Collection Time on Per Capita Wood Use

Potential Income	*No. households*	*% change*
Overall	3283	−14.20
First Quartile (< 22,059.54)	822	−10.45
Second Quartile (>= 22,059.54 and < 34,213.83)	820	−12.85
Third Quartile (>= 34,213.83 and < 55,737.3)	820	−13.58
Fourth Quartile (>= 55,737.3)	821	−19.91

TABLE 9. Effect of Forest Degradation on Total Collection Time of Households

Potential income	*Total time before degradation (in hrs)*	*Total time after degradation (in hrs)*	*Change in total collection time (in hrs)*
Overall	654.95	747.00	91.91
First Quartile (< 22059.54)	661.05	776.98	115.93
Second Quartile (>= 22059.54 and < 34213.83)	650.21	750.23	100.02
Third Quartile (>= 34213.83 and < 55737.3)	657.09	753.68	96.59
Fourth Quartile (>= 55737.3)	651.47	707.11	55.10

collecting rises, as shown in table 9, by about 14 percent on average, with a larger increase for poorer groups (presumably because wealthier groups substitute into LPG to a greater extent).

In order to estimate how this increased collection time is divided among members of the household, we estimated regressions for time allocation of male adults, female adults and children between household work, productive work and (firewood and fodder) collection activities, with respect to the same set of regressors as in table 4.[28] For the sake of brevity we do not show these regression results. We use these regression coefficients to estimate the impact of an hourly increase in collection times per bundle on labor allocation of women and children, shown in table 10. Collection time was not a statistically significant determinant of time allocation of adult males, so we do not show any predictions for them. Collection times impacted time allocation only for adult females, who are likely to bear the brunt of the increased forest degradation: of the average increase in 91 hours annually for each household in collection firewood, 68 hours is predicted to come from women. In addition, women are predicted to devote 43 hours more, annually to household tasks, and withdraw 122 hours from productive tasks. Aggregating across all categories of work, however, total hours worked by women is not predicted to increase. Similarly, there is almost no effect on total hours worked for children, as well as its allocation across different activities. Hence forest degradation is not predicted to increase child labor or women's labor; only a reallocation of women's time.

6. Policy Options: LPG Subsidies

The previous sections have argued that degradation of the mid-Himalayan forests adjoining villages with human settlement is likely to be aggravated in the future owing to continuing anthropogenic pressures. This is likely to exert a limited impact on the livelihoods of neighboring residents, which possibly explains any lack of effort among local communities to limit forest use. Hence the argument for external policy interventions rests on the importance of the non-local ecological externalities involved. If the scientific evidence suggests the ecological effects on soil erosion, landslides, and water flowing into the Ganges and Brahmaputra basins are significant, there is a need to consider policies that may reduce the dependence of households on neighboring forests.

28. Since many children do not work, we estimated a random effects tobit for child labor.

TABLE 10. Effect of Increased Collection Time (1 hr) on Women and Child Labor

Activity type	*Potential income*	*Change in hrs of women*	*Number of households with working children before change*	*Annual hours worked for children working before change*	*Annual hours worked for all children before change*	*Number of households with working children after change*	*Annual hours worked for children working after change*	*Annual hours worked for all children after change*
Domestic Work	Overall	43.43	3084	179.43	168.14	3045	175.31	162.20
	First Quartile	35.90	731	173.32	154.14	732	168.50	150.05
	Second Quartile	42.94	786	174.36	166.72	784	170.34	162.46
	Third Quartile	46.46	800	185.65	180.68	797	181.52	176.00
	Fourth Quartile	48.44	767	183.94	171.01	732	180.67	160.30
Productive Activity	Overall	−122.52	766	90.46	21.06	925	91.78	25.80
	First Quartile	−106.97	164	55.65	11.10	225	60.37	16.52
	Second Quartile	−126.69	192	100.36	23.44	242	100.93	29.71
	Third Quartile	−131.94	227	93.60	25.85	271	96.78	31.91
	Fourth Quartile	−124.46	183	107.39	23.82	187	110.48	25.04
Forest Collection	Overall	67.79	2225	141.33	95.55	2187	148.76	98.86
	First Quartile	37.62	560	103.16	70.28	581	108.78	76.88
	Second Quartile	53.38	578	132.81	93.39	575	142.89	99.96
	Third Quartile	67.95	577	152.09	106.76	571	160.61	111.57
	Fourth Quartile	112.22	510	180.74	111.73	460	191.89	107.00

Given the lack of any significant social norms, local collective action or state monitoring activities regulating forest use, successful interventions must act through their effect on individual household incentives to use firewood and fodder. The regression results in table 4 showed that use of firewood is related significantly to the cost of LPG. We also saw earlier that LPG is the only principal alternative primary source of household energy; kerosene and electricity are used only as secondary sources of fuel. Lack of reliable supply of electricity is often mentioned as the main reason why they do not rely more on electricity. The average number of hours per day that electricity was reported to be available was 14 hours in the summer and 11 hours in the winter. Only 20 households in the entire sample used kerosene as a primary source of fuel, despite the fact that practically every household purchased and used kerosene (mainly for lighting purposes). The average per capita annual income of those using kerosene as a primary fuel was Rs 9,614, compared with Rs 8,036 for those using wood as primary fuel, and Rs 14,060 for those using LPG as primary fuel. This indicates that the cost of kerosene was a factor for poor households in deciding to use wood as their primary fuel. Other factors also played a role in a household's preference for LPG over kerosene, as reported in household interviews.[29] Hence LPG subsidies represent one conceivable policy option for halting forest degradation. In this section we explore their effectiveness in curtailing household reliance on firewood, and the fiscal costs they may entail.

To get a better sense of the energy substitution between firewood and LPG, we can look at the separate per capita wood use regressions for summer and winter seasons displayed in table 4. LPG is primarily a source of cooking fuel, while firewood serves both as a cooking fuel and source of heat. There are virtually no substitutes for firewood as a source of heat in the winter months, while the demand for cooking fuel extends the whole year. Hence one would expect greater substitutability with respect to LPG during the summer. This is precisely what we see in table 4: the coefficient with respect to LPG price alone in the summer is –.05, against –.03 in the winter. The substitution effects with respect to the cost of collecting wood (with the exception of the interaction of collection time with education) are also stronger in the summer.

29. These reasons were as follows: (i) the availability of kerosene through government distribution outlets is intermittent; (ii) transportation and spillage of kerosene is a greater problem; (iii) kerosene stoves are noisier; (iv) cooking vessels turn black when kerosene stoves are used; (v) LPG burners are easier to operate and maintain than kerosene stoves; (vi) once an LPG cylinder is acquired it can be used for 3 months, whereas kerosene has to be procured repeatedly.

Table 11 shows estimated effects on annual per capita firewood use of Rs 100 and Rs 200 subsidy per cylinder of LPG for different quartiles as well as for the entire distribution, broken down into summer and winter. The cutback in wood use is predictably larger in the summer, but the magnitude of the elasticity for either season is striking: 38 percent and 55 percent respectively, averaging to a 44 percent increase for the year as a whole. Interestingly the effects are felt in all quartiles, not just among the wealthy: even for the poorest quartile the change in annual use is 37 percent. In short, LPG price cuts are expected to have large effects on use of firewood, quite unlike the effect of increased collection times by one or two hours. And they will affect the behavior of households across the board, not just the wealthy.

TABLE 11. Effect on Per Capita Wood Use Due to Fall in LPG Price by Rs 100 and Rs 200 of All Household

	Potential income	*Observation*	*% Change (Rs 100) mean*	*% Change (Rs 200) mean*
All Year	Overall	3286	–22.21	–44.41
	First Quartile	822	–18.55	–37.11
	Second Quartile	820	–22.08	–44.16
	Third Quartile	820	–22.35	–44.71
	Fourth Quartile	824	–25.83	–51.66
Winter	Overall	3283	–27.26	–54.52
	First Quartile	822	–22.53	–45.06
	Second Quartile	820	–27.22	–54.44
	Third Quartile	818	–26.85	–53.71
	Fourth Quartile	823	–32.42	–64.84
Summer	Overall	3283	–19.13	–38.26
	First Quartile	820	–16.19	–32.39
	Second Quartile	819	–18.51	–37.01
	Third Quartile	820	–19.61	–39.23
	Fourth Quartile	824	–22.19	–44.39

To estimate the fiscal cost involved, table 12 reports a random effect tobit regression for annual per capita LPG use, which incorporates both whether or not a household will use LPG, as well as the extent of use for those who do. The tendency to switch to LPG is higher among those with higher fixed incomes, smaller households, more education, land and small livestock, and less among those with more big livestock. These patterns are more pronounced when firewood collection times are higher. LPG use is also related to the cost of LPG (with a Rs 200 subsidy inducing a rise in LPG use by 4.4 cylinders per capita per year), and whether its availability

TABLE 12. Reduced Form Regression of Per Capita LPG Use

	All year–random effects tobit†
Potential Income	4.11E-06
	(2.65E-06)
Potential Income Sq.	–1.48E-11***
	(2.64E-12)
Fixed Income	6.33E-06***
	(1.03E-06)
Firewood Collection Time*PCPotential Income	–5.68E-06**
	(2.22E-06)
Fw. Collection Time*PCPotential Income*Big Livestock	–4.75E-07**
	(2.27E-07)
Fw. Collection Time*PCPotential Income*Small Livestock	1.40E-07***
	(4.08E-08)
Fw. Collection Time*PCPotential Income*Nonfarm Business Assets	4.68E-12***
	(1.80E-12)
Fw. Collection Time*PCPotential Income*education	6.16E-07***
	(6.60E-08)
Fw. Collection Time*PCPotential Income*Land	1.70E-07***
	(5.60E-08)
1/Household Size	1.88**
	(8.57E-01)
Household Size	–1.47E-01***
	(5.20E-02)
Fw Collection Time	1.27E-01
	(1.34E-01)
LPG price	–1.64E-02***
	(3.22E-03)
LPG Irregular Availability Dummy	–3.48E-01**
	(1.57E-01)
% forest area van panchayat	3.45E-03
	(2.73E-03)
% forest area sanctuary	–1.06E-02
	(7.47E-03)
% forest area other excluding DPF	–4.60E-04
	(2.41E-03)
Altitude	1.06E-03***
	(2.90E-04)
Population	–3.70E-04**
	(1.89E-04)
No. Households, Villages	3284,165, –1903.7217

Note: ***, **, * significant at 1 percent, 5 percent, 10 percent respectively, s.e. in parentheses.

† Random effect includes the additional village characteristics—time to jeepable road, time to block office, ethnic fragmentation, gini of land, snowfall and whether a village had electricity connection—all of which turned out to be statistically insignificant.

is irregular. All these results are consistent with the notion that households are trading off the costs of time spent collecting firewood against the pecuniary costs (and reliability in supply) of LPG.

Table 13 uses these results to predict the effect of LPG subsidies on LPG use. A Rs 100 subsidy per cylinder is predicted to raise the fraction of households using LPG from 7 percent to 36 percent. A Rs 200 subsidy will raise this proportion to 78 percent. For those in the bottom three quartiles currently using LPG, the Rs 100 subsidy will raise their LPG use significantly, though the effect on the top quartile (forming the majority of the current users) will be smaller (about 20 percent). The overall impact will be a five-fold rise in per capita LPG use from .07 to .39. The Rs 200 subsidy will have more dramatic effects, raising per capita use to 1.34. Hence LPG subsidies are likely to be very effective in inducing a large scale shift in household energy use towards LPG.

Table 13 permits us to estimate the fiscal cost of the subsidies. The Rs 100 subsidy induces 37 percent of households to use LPG at the rate of 1.07 cylinders per capita. Using the average household size of 5.3, this translates to a demand of 5.7 cylinders per year per household. Hence the subsidy will amount to approximately Rs 570 per using household. With 84 households per village there will be approximately 30 households using gas in each village, yielding a cost of Rs 17,000 per village, or Rs 200 per household annually, approximately 0.5 percent of their annual consumption expenditure.

The fiscal costs are substantially higher for the Rs 200 subsidy: 65 households will demand an average of 9 cylinders annually, yielding a cost of Rs 1,17,000 per village, or Rs 1,400 per household annually, approximately 4 percent of their annual consumption expenditure. A special annual grant of Rs 1,20,000 to each village panchayat in the mid-Himalayan region for the purpose of a Rs 200 subsidy per gas cylinder can thus be considered as a policy intended to induce substitution of household energy away from firewood. With the 829 Census villages in this region, this translates into a total cost of about Rs 10 crores annually.

Another policy option often discussed is to turn over state forests to community management, along the lines of the Uttaranchal van panchayats. Table 4 showed that the type of local forest does have an effect on household wood use. Van panchayat forests are associated with lower use of firewood compared to state protected (DPF) forests and sanctuaries, while non-DPF forests involve higher use than DPF forests. Hence community management is associated with reduced household reliance on firewood compared with

TABLE 13. Effect of Fall in LPG Price on Per Capita Gas Use of all Households

	Potential income	*Number of household using gas before change**	*Number of cylinders for households using gas before change*	*Number of cylinders for all households before change*	*Number of household using gas after change*	*Number of cylinders for households using gas after change*	*Number of cylinders for all households after change*
Fall in LPG Price by Rs. 100	Overall	229	0.95	0.07	1189	1.07	0.39
	First Quartile	16	0.36	0.01	195	0.70	0.17
	Second Quartile	23	0.45	0.01	236	0.79	0.23
	Third Quartile	44	0.51	0.03	311	0.92	0.35
	Fourth Quartile	146	1.23	0.22	447	1.48	0.80
Fall in LPG Price by Rs. 200	Overall	229	0.95	0.07	2576	1.71	1.34
	First Quartile	16	0.36	0.01	636	1.29	1.00
	Second Quartile	23	0.45	0.01	574	1.47	1.03
	Third Quartile	44	0.51	0.03	646	1.67	1.31
	Fourth Quartile	146	1.23	0.22	720	2.31	2.02

all other categories of forests. However, it turns out that this moderating effect is limited to those van panchayats that were judged by local villagers to be moderately or fairly effective.[30]

Moreover, conversion of 100 percent state demarcated forests to 100 percent van panchayat forests will reduce per capita firewood demand by 8 bundles annually, or approximately one fifth of annual consumption. The Rs 100 LPG subsidy will therefore be more effective than converting all state demarcated forests to van panchayat forests. Moreover, the considerable heterogeneity of monitoring effectiveness of *van panchayat*s implies that the impact of community management is unlikely to be uniform, and will be restricted to those that have effective monitoring systems.[31] The effect of LPG subsidies is likely to be more uniformly spread across different villages, since they would be likely to apply uniformly to household incentives in all areas.

6. Conclusion

In summary, we find considerable evidence of degradation of the mid-Himalayan forests, manifested mainly by high degrees of lopping for firewood and fodder collection. This form of degradation does not represent a substantial reduction in forest biomass, and would not be picked up by aerial satellite images. Yet it has considerable consequences for the time taken by local villagers to collect firewood, which have risen over 60 percent on an average over the past quarter century. Ecology surveys, household responses and ethnographic accounts suggest that state or community management of forests make little difference, with the exception of some *van panchayat*s in Uttaranchal. Since state monitoring and local community control seem quite ineffective, the pace of forest degradation depends mainly on household choices of fuel.

Our econometric analysis shows that these depend on living standards, occupational patterns, education and access to affordable modern fuels such as LPG. Economic growth is unlikely to have any impact on firewood collected from forests, while population growth is likely to raise it proportionately.

30. When we add a dummy for monitoring effectiveness of the van panchayat as evaluated by local villagers, the van panchayat effect vanishes, while the monitoring effectiveness dummy becomes large and significant.

31. See our companion paper (Baland et al (2006)) for further detail on this issue.

The reverse impact of degradation on living standards is surprisingly small: further degradation of a magnitude comparable to that observed over the past quarter century would lower living standards of local villagers by less than 1 percent, across the board. This may explain why local communities appear unconcerned about the need to conserve forests. The argument for external policy interventions must therefore be based on the importance of ecological considerations *per se,* and the related non-local externality on landslides, soil erosion and downstream river basins.[32]

LPG subsidies can be an effective policy option to relieve pressure on the forests. A subsidy to the tune of Rs 200 per cylinder is estimated to reduce firewood demand by 44 percent, and induce the proportion of households using LPG to rise from 7 percent to 78 percent. Community management of forests on the pattern of Uttaranchal van panchayats are also likely to moderate firewood demand, but their effect is likely to be less significant and less uniform. In the longer run, out-migration from mountain villages, modernization of occupational patterns (for example, decline in livestock-based occupations) and rise in education will ease the pressure on the forests further. Moreover, households will cut back on firewood use as the collection time rises.

Our ongoing research involves estimating growth and policy effects more precisely using a structural econometric model rather than reduced form regressions; and more careful estimates of van panchayat forest management. Some of the unresolved issues concern the ecological effects of forest degradation, and the magnitude of the non-local externalities. This will require an interdisciplinary effort combining expertise of ecologists, geographers and economists.

32. See Kumar and Shahabuddin (2005) for evidence relating grazing and firewood extraction with biodiversity in a Northern India forest, resulting from the heavier impact of these activities on particular species. They also find significant effects on tree height and girth.

APPENDIX

TABLE A-1. Estimates of Per Capita Fodder Collection (in Bundles)

	Random effects tobit
Potential Income	–1.74E-04**
	(7.76E-05)
Potential Income Sq.	3.51E-10***
	(9.00E-11)
Fixed Income	–6.48E-05**
	(3.12E-05)
Firewood Collection Time*PCPotential Income	1.87E-04***
	(6.43E-05)
Fw. Collection Time*PCPotential Income*Big Livestock	–2.06E-05**
	(9.36E-06)
Fw. Collection Time*PCPotential Income*Small Livestock	8.25E-06***
	(1.59E-06)
Fw. Collection Time*PCPotential Income*Nonfarm Business Assets	–1.22E-10**
	(5.98E-11)
Fw. Collection Time*PCPotential Income* education	–1.60E-06
	(2.02E-06)
Fw. Collection Time*PCPotential Income*Land	–7.24E-06***
	(2.10E-06)
1/Household Size	103.01***
	(20.3)
Household Size	–6.31***
	(1.12)
Fw Collection Time	–9.94**
	(3.92)
LPG price	2.37E-02
	(7.56E-02)
LPG Irregular Availability Dummy	–12.42***
	(4.05)
% forest area van panchayat	–3.79E-02
	(6.08E-02)
% forest area sanctuary	–1.69E-01**
	(8.30E-02)
% forest area other excluding DPF	1.45E-01**
	(6.66E-02)
Altitude	3.96E-03
	(7.40E-03)
Population	3.29E-03
	(6.06E-03)
Big Livestock	9.98***
	(8.04E-01)
Small Livestock	–1.67E-01**
	(8.07E-02)
No. Households, Villages, log likelihood	3284,165, –16418.902

TABLE A-2. Effects of Degradation and 10 percent Growth of Assets on Per Capita Fodder Collection for all Households

Potential income	*Impact of*	*Number of households collecting before change*	*Annual bundles collected by collecting households before change*	*annual bundles collected by all households before change*	*Number of households collecting after change*	*Annual bundles collected by collecting households after change*	*Annual bundles collected by all households after change*
Overall	Increase in collection time by one hour	3241	71.08	70.00	3204	62.73	61.07
First Quartile		815	71.88	71.27	810	63.12	62.20
Second Quartile		816	75.62	75.07	809	67.24	66.18
Third Quartile		816	72.32	71.80	814	63.50	62.89
Fourth Quartile		794	64.29	61.88	771	56.77	53.05
Overall	Increase in Productivity of Assets	3245	74.64	73.59	3245	74.51	73.47
	Land	3241	71.08	70.00	3244	69.43	68.44
	Big Livestock	3241	71.08	70.00	3247	72.44	71.47
	Small Livestock	3241	71.08	70.00	3245	72.82	71.81
	Education	3241	71.08	70.00	3245	74.31	73.28
	Non-Farm Business Assets	3241	71.08	70.00	3244	69.02	68.04
First Quartile	Increase in Productivity of Assets	669	72.16	71.73	669	72.01	71.58
	Land	742	71.70	71.22	742	70.55	70.07
	Big Livestock	679	71.16	70.74	679	71.92	71.50
	Small Livestock	676	71.12	70.71	676	71.96	71.53
	Education	669	70.98	70.56	669	72.15	71.72
	Non-Farm Business Assets	727	71.66	71.17	727	70.04	69.56
Second Quartile	Increase in Productivity of Assets	800	86.13	85.07	800	86.67	85.60
	Land	814	75.45	74.72	814	73.54	72.83
	Big Livestock	805	75.47	74.64	804	76.83	75.88
	Small Livestock	802	75.59	74.75	801	78.70	77.73

	Education	801	75.72	74.88	800	84.83	83.78
	Non-Farm Business Assets	813	75.30	74.56	812	73.03	72.23
Third Quartile	Increase in Productivity of Assets	852	73.93	73.58	852	73.32	72.97
	Land	818	73.06	72.53	818	70.89	70.37
	Big Livestock	846	73.63	73.11	846	74.47	73.94
	Small Livestock	849	73.55	73.12	849	74.12	73.69
	Education	852	73.56	73.21	852	73.93	73.58
	Non-Farm Business Assets	822	73.24	72.71	822	70.50	69.99
Fourth Quartile	Increase in Productivity of Assets	924	67.13	65.16	924	66.89	64.92
	Land	867	64.56	62.33	870	63.27	61.29
	Big Livestock	911	64.76	62.63	918	67.10	65.39
	Small Livestock	914	64.78	62.59	919	67.14	65.22
	Education	919	64.79	62.55	924	67.13	65.16
	Non-Farm Business Assets	879	64.67	62.46	883	63.13	61.25

TABLE A-3. Data Appendix

		ALL		*Himachal Pradesh*		*Uttaranchal*	
Variable	*Description*	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*
Potential Income	Potential income is the estimated maximum possible income from self employment if all available labor not permanently employed was engaged in self employment. (in Rs) (current prices)	48271.79	59803.1	39410.15	45609.37	57026.28	70016.8
Per capita consumption	Per capita consumption (Rs/year, current prices)	8646.40	5264.79	7887.02	5563.05	9397.06	4838.22
Head count poverty rate	Percent households below state poverty line	14.3		24		4.8	
Household size	Actual Household size	5.74	2.26	5.87	2.25	5.61	2.21
Household size	Household size (adult equivalent)	4.99	1.94	5.11	1.98	4.88	1.90
Proportion of hh purchasing wood	Percent households purchasing wood	3		2		4	
Proportion of hhs not collecting	Percent households not collecting wood	0.1		0.2		0.1	
Per capita wood used	Per capita wood use (bharis/year)	43.57	20.92	46.86	24.68	40.31	15.72
Per capita wood used in summer	Per capita wood use in summer(bharis/year)	22.42	14.17	24.61	17.89	20.26	8.59
Per capita wood used in winter	Per capita wood use in winter(bharis/year)	21.15	10.47	22.25	11.91	20.05	8.69

Shadow wage	Estimated shadow wage (Rs/hour)	1.21	1.25	1.02	0.85	1.41	1.53
Land	All cultivable land owned by the household; used largely for agriculture and/or horticulture; measured in bighas (5 bighas = 1 acre)	7.27	6.13	7.13	6.71	7.41	5.48
Non-farm business assets	Market value of the business (in Rs)	16851.96	87389.63	11498.75	76577.7	22143.72	96631.5
Big livestock	Number of cows, buffaloes and mules in the household	3.67	2.30	3.12	2.02	4.21	2.43
Small livestock	Number of goats and sheep in the household	6.49	20.03	7.06	21.74	5.92	18.17
Education	Sum of years of schooling of all adult members in the household	13.44	12.00	13.35	12.40	13.54	11.59
Fixed income	Sum of annual income from wage employment and pension (in Rs)	14468.72	38410.94	19608.23	46928.27	9388.22	26567.4
Firewood collection time	Time to collect one bhari (in hrs)	3.31	0.54	3.28	0.65	3.34	0.39
LPG Price	LPG price (in Rupees) per cylinder	299.02	34.01	307.48	29.00	290.66	36.45
LPG Irregular Availability Dummy	Dummy if LPG is not always available.	0.48	0.49	0.55	0.49	0.42	0.49
% Forest Area Van Panchayat	percentage of neighboring forest area consisting of van panchayat forests	14.33	29.19	0	0	28.49	35.93
% Forest Area Sanctuary	percentage of neighboring forest area, where villagers are not allowed to collect altogether	4.25	20.18	0	0	8.46	27.83

(Table A-3 continued)

(Table A-3 continued)

Variable	Description	ALL		Himachal Pradesh		Uttaranchal	
		Mean	*Standard deviation*	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*
% Forest Area Other Excluding DPF	percentage of neighboring forest area consisting of all other types of forest (excluding DPF, RF, van panchayats, sanctuaries)	16.00	29.43	20.37	34.55	11.68	22.49
Proportional Income Loss	Estimated shadow wage, times increased collection time, as a proportion of actual income (in Rupees)	0.01	0.01	0.01	.01	0.01	0.004
Altitude	Elevation above sea level (mts)	2057.27	258.62	2094.04	258.93	2021.00	253.21
Population	Population of village	439.39	365.93	545.37	473.91	334.63	149.14
Number of Observations		3291		1636		1655	

Comments and Discussion

Andrew Foster: In recent years, development economists have given increasing attention to empirical analyses of the processes underlying the use and protection of environmental resources. A particularly fruitful literature has emerged on the subject of forest cover. The key questions here are what are the key drivers of forest cover and forest quality change, whether policy interventions into the management of local forest resources are justified on grounds of equity or efficiency given the presence of local institutions that may or may not preserve forest resources, and, if so, what types of policies are likely to be most effective. In the process of undertaking this research it has become clear that there is a high return to the integration of economic theory, household-survey methods, careful ecological measurement, and the modeling of ecological processes.

This paper is an important contribution to this emerging literature in a number of respects. First, a detailed large-scale survey has been conducted by the authors with a particular focus on the issue of the use of forest product extraction. Existing multi-purpose surveys do not have sufficient detail on this issue to provide a compelling basis of inference. Second, the survey has been linked to a careful ecological assessment of forest quality. These latter data permit a more nuanced understanding of how forest cover is being affected by changing economic conditions than would be possible otherwise. They also provide some basis for thinking about the extent to which current practices are sustainable given natural processes of forest renewal. Third, data analysis is organized in the context of a reasonably constructed model of household behavior that yields important insights in terms of how firewood use varies across households, the potential for substitution across different fuels, and the likely consequences of future growth in population and income. Fourth, the authors sketch the costs and benefits of a plausible mechanism for forest protection, the subsidy of alternative fuels for cooking and heating. Finally, the authors address the issue of the strength of local externalities associated with extraction of forest resources. They come to a novel conclusion that has not, to my knowledge, been demonstrated elsewhere: that, despite the evident degradation of natural systems, the magnitude of the local externality generated by this degradation is small.

It is worth considering this latter contribution in some detail. At the heart of the issue is whether institutions are in place at the level of the community that largely internalize potential externalities that may arise given individually-rational maximizing behaviors at the level of the household and the public access nature of forest resources. Put another way, in the absence of effective property rights over the products of the forest or community institutions that substitute for these rights, there will be overinvestment in forest good collection and overconsumption of forest goods relative to what would obtain if household behavior were sufficiently coordinated. But how do we measure the extent of these efficiencies and thus the need for and or efficacy of new policies that protect forest resources?

As noted, the authors conclude that in the case of the mid-Himalayan villages in their sample, the local externality is small. The primary source of evidence here is the low opportunity cost of the increment in forest good collection time that may be attributable to forest degradation over the last 25 years. This seems a plausible basis for inference but the relationship between those two concepts may not be obvious to readers of this paper as the authors do not formally model interaction among households in the forest sector. To help illustrate the case I have developed a simplified model that does take this additional step. For analytic simplicity the model focuses on the source of static local externalities and ignores dynamic ones. That is, I focus on the static tragedy of commons in which households receive the average product of labor in forest wood collection and disregard dynamic externalities arising from the fact that households (or the village as a whole) do not internalize the possible future benefits (arising, say, from natural renewal) of limiting forest good extraction today. This simplification would be problematic if the relevant forests were in danger of generating a large-scale ecological collapse; however, I concur with the authors that such a collapse is a remote possibility given the recent history and likely future economic, demographic, and natural resource trajectory of this area.

Take the simple case in which household utility u() is defined as a log-linear function over forest good f and consumption of other goods c

$$u(c, f) = \beta \ln(f) + c.$$

Total village forest good production is based on a Cobb-Douglas production function of total forest land and total forest labor with the share of village forest good being allocated to households based on their share of total labor. So a given household's forest good consumption is

$$f = A^{(1-\alpha)} (Nl_f^*)^{\alpha}\, l_f/(Nl_f^*)$$

where A denotes total forest land, l_f denotes household labor, l_f^*, the average extraction by other households, and N the total number of households. The household budget constraint is

$$c + \tau(l_f - l_f^*) + wl_f = wT$$

Where w the wage, T is the labor time endowment, and τ denotes a tax on forest labor that may be implemented by the village to control access, with proceeds redistributed on a lump sum basis to the household. In the *laissez-faire* case, of course, $\tau = 0$.

Assuming N identical households it follows immediately that

$$l_f = l_f^* = \beta/(w + \tau),$$

that the village welfare maximizing tax is

$$\tau = w(1 - \alpha)/\alpha,$$

and that the income-equivalent gain from village welfare maximization relative to lassaiz faire as a fraction of the value of total labor income is

$$(\alpha \ln(\alpha) - \alpha + 1)(l_f/T)$$

The first term in parentheses ranges from 1 to 0 as the labor share α ranges from 0 to 1. Thus in the context of this simplified model it is clear that the importance of the local static externality is governed by the share of time spent in forest labor as the authors imply. It is also sensitive to the labor intensity of forest good extraction which can be estimated, in the model, from the authors' data using information on changes in collection time per hour, the total number of households, and the wage change.

Of course this model misses a great deal. It does, however, highlight a number of key factors that can lead local externalities to be small. First, it shows, as noted, that a low labor contribution is indicative of a small local externality. Second, a small local externality can arise if the labor share is high, which minimizes the difference between the average and marginal products of labor in forest good production. Third, the price elasticity of demand, which is fixed at one in this model for notational simplicity, is important. The local externality will be larger if demand is relatively price inelastic—and thus smaller if substitute fuels such as LPG are available and relatively cheap. Fourth, rising wages by reducing forest labor allocation will reduce the local externality. But population growth, by depressing wages, may have the opposite effect.

In summary, this paper is an important contribution in terms of what it tells us about forest policy. In particular, it suggests that community management of forest resources, even among communities with effective governance, may not lead to substantial improvements in forest resources. If there are strong external benefits to protecting local forests arising from issues of downstream silting, species protection, or global warming then it is likely that external subsidies will be needed to support these protections. The LPG subsidy approach seems to be a potentially promising avenue to consider in this regards. But in addition to these policy insights, this paper is important because it provides a path forward in terms of gaining a better understanding of the complex natural resource issues that will face village India over the next decades.

Devesh Kapur: Comments on "Managing the environmental consequences of growth: Forest Degradation in the Indian Mid-Himalayas."

India's galloping growth rates (and high projected rates), coupled with the country's resource constraints, mean that the environmental implications of this growth are a matter of growing concern. Hence, the importance of the issues raised by this paper is quite obvious. Nearly two decades ago, N. S. Jodha (1986) raised the question: in the Indian context, does poverty lead to greater reliance on the commons and subsequent degradation of the commons? Or do increasing levels of wealth lead to a greater use of the commons, at least initially?

The answer is surprisingly complex. The scholarship on resource use and management has highlighted a bewilderingly large number of variables that affect common property resource management. Knowledge about the magnitude, relative contribution, and even direction of influence of different causal processes on resource management outcomes is still poor. Agrawal and Chhatre (2006), in their analysis of community forest governance in Himachal Pradesh, identify 24 variables that were statistically significant, ranging from biophysical (4), demographic (5), economic (6), institutional (5) and socio-political factors (4).

Even using this model, there are concerns regarding possibly omitted variables, causal mechanisms and the dynamics of different variables. Resource characteristics and biophysical variables form the context within which socio-political and economic characteristics of users and institutional variables shape resource management outcomes. Institutional arrangements can range from self-initiated systems, cooperatives, corporate clan-owned forests, sacred forests, and co-managed forests. Although community participation in common property resource management has been fashionable, the term is often not very specific, whether as a spatial unit or a social grouping with shared norms. Clearly there are multiple interests and actors within communities that influence decision-making, and institutions both within and external to the group shape the decision-making process. Even the incentives facing a community are not unambiguous. On the one hand, one might expect villagers to make greater efforts to protect forests when it clearly affects their livelihoods. On the other, if villagers do not view a forest as important to them, its condition may improve because villagers will extract less from it. While it may not be impossible to identify a set of necessary and sufficient conditions that affect common property local resource governance, it certainly appears to be very difficult.

Consequently, the paper's research design and the meticulousness with which data has been gathered and analyzed is especially commendable. The paper finds an absence of any effects of poverty or growth on forest quality. Moreover, it finds no Kuznets-curve type patterns on the environmental-growth tradeoff. Instead, it concludes that anthropogenic pressures on forests are more likely to occur due to demographic pressures than due to economic growth.

The first issue raised by the paper relates to the measurement of forest degradation—the dependent variable. In the 1980s, the National Remote Sensing Agency (NRSA), under the Department of Space, was created to analyze satellite images of the earth, including forest cover and degradation. The Forest Survey of India (FSI) became quite defensive and argued that the NRSA estimates were much lower than its own estimates. However, recently Prabhakar et al. (2006) used a software program instead of humans to interpret satellite images and argued that data from the Forest Survey actually considerably underestimates the degree of degradation in Indian forests. The larger question—one common to many of the papers in this volume—is the troublsome quality of official data. Since policy debates, from poverty estimates to agricultural growth, depend on accurate data, this issue of data quality is fundamental. When there is so much argument on the facts themselves, the interpretation of the facts becomes an even larger problem.

The second fundamental issue relates to the determinants and implications of local-level collective action on the management of the commons. The literature reveals a large number of variables that affect the management of the commons, ranging from those that affect the characteristics of the resource system (for example common water or forest resources), group characteristics (social heterogeneity such as class, gender or caste), institutional arrangements, and the external environment, especially the role of the state. Recent work in other parts of India, such as Stuart Corbridge et al. (2004) in Jharkhand, and Agrawal and Chhatre (2006), and Chhatre and Saberwal (2005) in Himachal Pradesh, appear more sanguine about collective action efforts than does this paper. Since all look at forests as the common property resource, are the differences mainly due to differences in the institutional context or the purposes for which the resource is most used? For instance, for Corbridge et al. the pressures in Jharkhand relate to deforestation (especially by the timber mafia) rather than forest degradation, which is not an issue in this case.

A third issue is the intra-household allocation of labor due to an increase in firewood collection times, as a result of forest degradation. One might expect a larger investment of time spent on collecting firewood, especially for young women, therefore impacting time spent on their education. However, there does not seem to be a correlation between deforestation and educational outcomes. Is this because education is measured by years of schooling rather than learning abilities?

A fourth issue is the choice in sources of household fuel. There are substantial subsidies for kerosene and LPG in India, and in most cases when poor households switch from firewood, they begin to use kerosene, only later switching to LPG. LPG cylinders (even smaller ones) are much heavier to carry on winding hill tracks away from the main road, while kerosene can be carried in smaller quantities and can be used for lighting as well. However, in this study, households did not seem to switch from firewood to kerosene, but instead jumped straight to use of LPG. What factors influenced this household preference for LPG?

The fifth issue (one which the paper refers to) is the precise nature of externalities. Admittedly, it is very hard to measure externalities, especially global ones; however, if one is advocating subsidies, then one has to estimate these externalities in order to give policy makers an idea of the appropriate quantum of subsidies. For instance, although there is an initial suggestion that deforestation increases either the intensity or the magnitude of natural disasters, the paper neither defines nor measures them.

The sixth question hovers around what one might call "modernization" in a sociological sense. The paper very nicely highlights one contributing factor to increasing forest degradation: the rise in the number of households, due to an increase in the number of nuclear families. Since this change is occurring without a corresponding modernization in occupational structures, it contributes to an increase in the demand for fuel. However, the negative impacts of this increasing demand depend considerably on future demographic trends. In Himachal Pradesh, the Total Fertility Rate (TFR) has declined from 2.97 in 1992–93 to 2.14 in 1998–99 and 1.94 in 2004–05 (that is, below replacement levels), while in Uttaranchal there has been a marginal drop from 2.61 to 2.55 between 1998–99 and 2004–05. This may partly be due to the lower levels of education in Uttaranchal: the percentage of the population with no education was 33 in Uttaranchal in 2005–05 versus 19 percent in Himachal.[1] Thus demographic trends in Himachal may portend a more sanguine future for the forests there, as compared with Uttaranchal.

Seventh, while the paper documents a sharp reduction in the number of livestock (ownership of large animals dropped by a third, while ownership of smaller animals such as sheep and goats dropped by a little more than half over a 25-year period), it is unclear from the paper if this is an equilibrating mechanism that reduces the community's demand for fodder in response to a growing demand for firewood. Since in the case of small animals, the biomass demand is greater for foliage, whereas for energy the demand is greater for branches, this shift in biomass demand is likely to result in larger undergrowth, but a degraded forest.

The paper mentions in-migration in the villages but does not discuss out-migration. One interesting feature about Himachal and Uttaranchal is that these states have some of the highest rates of recruitment in the Indian army. This would augment incomes through remittances and perhaps also gradually induce changes in behavioral and occupational patterns.

Policy Options

The empirical results clearly point to a growing energy demand (for heating and cooking) in a context of occupational and spatial immobility, as the principal reason for forest degradation. The energy needs of the villagers drive the case for LPG subsidies rather than kerosene, which is not used much in these villages. Might a better longer-term solution lie in policy options that would increase local externalities from the use of forests, thereby increasing the motivation of villagers to protect their forests?

For instance, it might be possible (at least in certain areas) to leverage developments in micro-hydel technologies, which allow for pico-hydel plants of less than 100 KW and which require a head of barely one meter.

1. Data from the National Family Health Surveys.

Although most of these villages are electrified, power supplies are irregular (with power available for only a few hours each day) and there are high transmission and distribution costs. However, micro-hydel technologies are fairly simple, do not require a major capital investment and can be managed on a village-level, providing a modest but reliable power supply to the village. These micro-hydel power stations could potentially create a virtuous cycle, creating strong motivation for the preservation of the commons. If villagers can see direct and visible links between the preservation of the commons and the maintenance of the water supply to power the micro-hydel electrical sources used in their village, there is much greater incentive to protect the commons. The creation of these links could be fundamental to incentivizing the protection of forests. Thus a better use of subsidies might be for reducing the capital costs of small turbines used in these power plants.

The second policy issue is the need to create non-agricultural livelihoods, given the limited scope for economic activities in the areas of agriculture and livestock. Occupational modernization in these areas can only occur either if people migrate or if there is a growth in services, such as eco-tourism. The latter, however, will still require alternate sources of energy.

A third policy issue concerns the role of the state, especially regarding its management of forests. Direct state management of forests has not produced good results. The shift to co-management, through joint community-state partnerships, has not been much more successful. Government officials' involvement in community decision making appears to be negatively related to forest condition and prospects for conservation (Kumar and Vashisht 2005). In this study as well, forest guards do not seem to play much of a role. This is both surprising and sobering. The success of Himachal Pradesh in providing primary education gives the impression that the state government is an effective manager of common properties. Yet even in Himachal, where the state government is supposedly more effective than other states, it is not particularly effective in any absolute sense. Indeed, all the papers in this conference seem to convey the same message-wherever there is any intervention by the Indian state, its interventions are either insignificant or inimical.

General Discussion

Kirit Parikh found a couple of the empirical results counter-intuitive. He would not have expected any link between the form of forest management (community vs. state) and firewood consumption and was surprised that the empirical estimates showed that firewood consumption was lower where forests were community managed. He was also puzzled by the lack of income elasticity of LPG use, since in urban areas LPG was demonstrably a superior good. A third empirical result that was counter-intuitive was that ownership of large animals was associated with increased firewood use: his argument was that the dung produced by large animals would substitute for firewood as a fuel source.

Surjit Bhalla expressed surprise that there was no apparent reduction in firewood use as income and wealth rose. He felt that there must be a point of inflection at which firewood became a less preferred fuel source. **Kaushik Basu** noted that, given the very low income of the poor in India, a relatively small income effect of increased firewood collection time could still be hugely significant in terms of reduced welfare. **T. N. Srinivasan** felt that it was inappropriate to ignore market wage rates completely since they influenced the opportunity costs for households in choosing between wage employment and self-employment in household production. **Siddharth Roy (Tatas)** referred to an experience in a different region of India, namely Kutch, where the provision of a technological alternative, namely biogas plants, significantly reduced time for fuel collection, allowing womenfolk to undertake other activities.

Rinki Sarkar confirmed that kerosene was extremely rationed in supply and therefore used only for lighting, not heating or cooking. Electricity supply was too erratic to be trusted despite the abundance of hydropower assets in the region. Community managed mini-hydel plants were certainly a technological option, but their prevalence was so far quite limited. The low income elasticity of demand for firewood reflected its role in both heating and cooking; there was as yet no effective replacement for it as a heating source. **Kirit Parikh** suggested that separate demand functions be estimated for summer and winter to differentiate the price sensitivity of firewood as a source of heating versus cooking.

Responding to T. N. Srinivasan, **Dilip Mookherjee** noted that there was considerable seasonality in market wage rates; market wages, on annual basis, were intra-marginal; the effective margin for opportunity cost was provided by self-employment. He also clarified that the basis for calculating the price elasticity of LPG was largely intra-village, thereby controlling for differences in distribution based on problems of access. Finally, he accepted that a dynamic formulation of their model might generate additional insights, but his own judgement was that the size of the local externality would remain relatively small, and the incentives for collective action correspondingly weak.

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