POVERTY, COMMUNITY CONTROL AND THE ENVIRONMENT: EVIDENCE FROM FIREWOOD COLLECTION IN NEPAL[1]

Jean-Marie Baland, Pranab Bardhan, Sanghamitra Das, Dilip Mookherjee and Rinki Sarkar

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1. INTRODUCTION

Sustainable development has been one of the buzzwords of the 1990s, a problem of global dimension which is variously believed to be the result of poverty, inequality, population pressure, commercialization, agricultural intensification, inappropriate market incentives, property rights and/or local collective action institutions. While many different hypotheses with contrasting policy implications have been advanced, there is a remarkable paucity of concrete empirical studies that help discriminate between them. This paper focuses on a specific environmental resource, firewood, in the context of rural Nepal, where concerns about deforestation have been expressed in terms of a `crisis' (Brower (2000)). Our purpose is to study determinants of household firewood collections, in terms of both household and community attributes, based on the World Bank 1995-96 Living Standards Measurement Survey (LSMS) data for a sample of approximately 2000 households in 215 Nepalese villages. While data limitations prevent a direct assessment of deforestation, defined as changes in forest stock over time, we focus instead on explaining cross-sectional differences across households and communities with regard to firewood collection, a key determinant of deforestation. For this purpose we model collection incentives and estimate resulting behavioral patterns at the level of individual households, and examine how these were affected by local institutions governing firewood use, of both formal and informal kinds, besides household attributes, local demographics, markets, infrastructure and geography.

There is little doubt that forests represent a key environmental resource, valuable both to local populations as well as to the planet at large, which are currently subject to depletion at an alarmingly high rate in developing countries, and particularly in Nepal. World Bank estimates carried out in 1995 suggested that global wood consumption was likely to exceed sustainable global yield by the year 2000, with the gap widening substantially by 2025. Forest cover was falling at the annual rate of 0.7% in Africa, 1.2% in Asia and Pacific region, and 0.8% in Latin America and the Carribean between 1980 and 1990.[2] For those living near the forests, shrinking forests imply reduced supplies of key energy sources such as firewood and charcoal, increased time and effort involved in gathering firewood, and reduced supplies of livestock fodder, fertilizer and mulch.[3] Moreover, the effects of deforestation extend far beyond their impact on the livelihood of those located near the forests, affecting the resource base of entire national economies: decline in forest cover at the source of river water causes downstream decline in soil fertility owing to erosion of topsoil cover, reduced irrigation input and hydropower capacity owing to altered water runoff into rivers and desalination of water.[4] For instance, deforestation in Nepal has been held principally responsible for a significant drop in major foodgrain yields since the 1960s (estimated at 35% between 1960 and 1980), and for the disastrous 1988 monsoon floods in Bangladesh,

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[2] See World Bank (1995, Table 1.2 and Figure 1.2)).

[3] In numerous developing countries in South Asia and sub-Saharan Africa reliance on woodfuels as a percent of total primary energy exceeds 70%, according to various World Bank/UNDP Energy Assessment exercises. In Nepal 73% of the LSMS sample reported using firewood as their primary cooking fuel, and approximately 90% of all wood consumed in Nepal is for fuelwood (Bluffstone (1995)).

[4] See Pearce and Turner (1990, Fig 22.1).

owing to resulting soil erosion.[5] It has caused increased landslides and vulnerability to earthquakes.[6] Even wider consequences include destruction of habitat, global warming and depletion of the ozone layer.

It is therefore imperative to understand the causes of such rates of deforestation, and policy measures that may arrest their rapid rate. Unfortunately, there is much disagreement among social scientists and ecologists on the chief causes of environmental degradation. One dominant hypothesis (e.g., expressed by the 1987 World Commission on Environment and Development, often referred to as the Brundtland Commission) assigns to local ***poverty*** a key role in determining the rate of environmental degradation. This is based on the notion that the poor rely disproportionately on common property resources such as open access land, forests or fisheries. According to this view, environmental degradation requires the reduction of poverty, whether through processes of growth, or via public intervention. Other authors assign a primary role instead to ***population pressure***, whether the result of demographic transition, or patterns of migration. In Nepal, for instance, many ecologists and geographers have assigned population growth the blame for environmental degradation.[7] An alternative view (Ostrom (1990), Somanathan (1991), Jodha (1997)) assigns primacy to ineffective ***community control*** resulting from lack of property rights and weak collective action within local communities concerning the use of common property resources. It is argued that changes in assignment of property rights --- widespread privatization of common property lands, for instance, or public appropriation and subsequent mismanagement of state forests --- have shrunk the rights, capacities and motivation of traditional communities to manage and utilize local forest resources. According to this view, poverty, economic inequality or social stratification may have a role to play, but only insofar as they enhance or undermine the effectiveness of local governance mechanisms. [8]

Yet other hypotheses place major emphasis on factors such as ***commercialization and agricultural intensification*** causing conversion of forest land to agricultural land, and changes in agricultural technology that change the degree of reliance on ecofragile natural resources (Jodha (1980, 1985, 1986), Leach and Mearns (1988), Hansen (1993), Foster, Rosenzweig and Behrman (1999)). Rising agricultural productivity and market integration motivates extension of arable lands at the expense of forest land. Moreover, commercialization and various forms of state intervention may rupture the fabric of social cooperation within rural societies, and alter patterns of consumption in ways that threaten the environment (Baland and Platteau (1996)). Other authors, however, suggest that market integration may produce countervailing pressures, via expanding labor market and crop diversification opportunities that reduce dependence on natural-resource-dependent occupations such as livestock-rearing, and enhance availability of woodfuel substitutes and energy conservation cooking methods (Bluffstone (1995), Amacher, Hyde and Kanel (1996), and Sarkar (1998)).

To what extent have the foregoing hypotheses been validated? Knowing this is an essential first step in designing effective policies aimed at arresting deforestation: should reducing poverty and inequality be the first order of importance, or should it be to reduce population growth and influence migration patterns? Should policy makers focus instead on forest rights and management systems? Or alternatively on diffusion of agricultural practices, crop diversification, or modifying accessibility to markets? Existing economic theory is not particularly useful, partly because it provides ambiguous answers to many of these issues (see, e.g., Bardhan and Dayton-Johnson (1997) or Baland and Platteau (1997, 1998)), and in any case cannot provide a quantitative assessment of the relative importance of different hypotheses. It is imperative, therefore, to proceed to empirical measurement and testing. While the area abounds with case studies, historical accounts and empirical analyses, most of these do not provide a way of discriminating between competing explanations, nor in distinguishing between causes and effects of environmental degradation.

Our methodology involves studying how firewood collection incentives at the level of individual households are shaped by household attributes (wealth, occupation, education, caste, demographics, location) and village attributes (geography, infrastructure, demographics, market prices, communal rights, inequality, poverty and social stratification). Since the LSMS data concerns samples of 10-12 households across 215 villages at a single point of time, we are able to decompose the variation in firewood collections into inter-household and inter-village differences. Underlying this is a

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[5] See Bluffstone (1995) and Myers (1991) for relevant citations.

[6] Myers (1986) provides a comprehensive discussion of the environmental repercussions of deforestation in the Himalayas.

[7] See Eckholm (1975,p.189), Karan and Ijima (1985, p.71) and Myers (1986, pp 64-65).

[8] Historical accounts of the origins of deforestation in Nepal which support this point of view are provided by Mahat, Griffin and Shephard (1986) and Metz (1991).

model where at one level individual household incentives are shaped by the market and institutional environment which it takes as given; at the next level local market and institutional variables (such as property right regimes and informal collective action institutions) are explained by village geography and socio-economic parameters affecting the nature of local collective action such as social stratification and asset inequality. This approach enables estimation of relative quantitative significance of both direct and indirect (i.e., operating through their impact on collective action) effects of poverty and inequality, village demographics (population size and composition across caste, age and sex categories), geography (elevation, location, forest proximity) and commercialization (occupational structure, proximity to markets and towns, prices etc.) The econometric approach followed uses instrumental variable methods to identify the effects of endogenous variables at both household and village levels, besides taking into account the censored nature of firewood collections (e.g., one third of the households do not collect any firewood at all) and various explanatory variables (e.g., many households are not below the poverty line, do not own any cows, and are not educated).

The paper is organized as follows. Section 2 reviews existing literature pertaining to alternative hypotheses of principal causes of environmental degradation in developing countries. Section 3 outlines the model underlying our empirical analysis, Section 4 describes the data, and Section 5 the econometric methodology (while the relevant technical details concerning the estimation procedure are provided in the Appendix). Section 6 then presents the main results. Section 7 concludes with a brief summary of the results, and discusses the principal shortcomings of the analysis.

2. EXISTING LITERATURE

We classify the existing literature according to the principal hypotheses concerning environmental degradation that have been postulated and empirically investigated, particularly in the context of Nepal and India.

The Poverty-Environment Hypothesis

Based on a number of illustrative case studies, the 1987 Brundtland Commission and the 1990 Asian Development Bank Report on Economic Policies for Sustainable Development pointed to poverty as the most important common denominator in instances of severe environment degradation. The ADB report concluded, for instance, that ``All reports confirm the hypothesis put forward by the Brundtland Commission that amelioration of poverty is a necessary and central condition of any effective program to deal with environmental concerns.''[9] Since then the poverty-environment hypothesis has occupied a central role in both academic literature and policy discussions, while it has been modified in a number of different directions (Lele (1991), Duraiappah (1998), Barbier (1997, 1999)). As Duraiappah (1998) elaborates in a recent review of this literature, the basic form of this hypothesis postulates a unidirectional link from exogenous poverty to degradation. This is based on the notion that the poor disproportionately rely on common property resources (CPRs), owing to imperfect capital markets and insecure land tenure systems (which constrain their access to credit and other key input markets, shorten time horizons, and limit their ability to invest in improved land and resource management strategies). Accordingly, anti-poverty policies are necessary to halt degradation, whether through market-driven growth processes or via directed antipoverty programs.

At the next level of sophistication, this hypothesis incorporates a reciprocal dynamic effect of environmental degradation on poverty: shrinking lands and CPRs hurts the poor the most, exacerbating their poverty.[10] This renders

[9] Cited in Jalal (1993, p.7).

[10] There is a substantial literature in the context of India and Africa, concerning the extent of dependence of the poor on CPRs, surveyed by Beck and Nesmith (1999). It has focused on quantifying the extent of reliance on common property resources (CPRs) by households in different economic categories, the decline in CPRs over certain periods of time, identifying the composition of relevant CPRs in different regions, and of the central role of women and children in CPR use (Agarwal (1997)). The most extensive empirical analysis, carried out in by Jodha (Jodha (1986) and summarized in Jodha (1992, 1997)) also examines the correlation between CPR decline and a select number of factors in isolation, such as occupational change, degree of commercialization, social stratification, dependence on state patronage, and privatization. These typically fall short of a more comprehensive econometric analysis of different sources of forest use or appropriation: e.g., they do not help assess the impact of one causal factor in isolation, while

poverty endogenous, leading to hypotheses of `cumulative causation' and `poverty-environment traps' (Lopez (1998), Maler (1998)). Extensions of these theories incorporate the role of other factors, such as market failures, institutional failures, technology and cultural values, but nevertheless still put the links between poverty and environmental degradation at the center (see, e.g., Figure 3 in Lele (1991)). Accordingly, Jalal (1993), Chief of the ADB Office of the Environment, listed the following two policy approaches to sustainable development in a frequently cited article: poverty alleviation, and integration of environmental concerns in development policy (i.e., efforts to modify market, institutional and technological parameters).

Population Pressure

Ecologists and geographers have frequently pointed to population growth as a principal cause of exacerbation of the tragedy of the commons, in a tradition going back to Garrett Hardin's celebrated article. In Nepal's context, for instance, Eckholm (1975), Karan and Ijima (1985) and Myers (1986) assign principal blame for its deforestation. Population growth rates accelerated from below 1.2% per annum prior to the 1940s, to 2% and over since then, rising to 2.6% in the 1980s. The highest rates of deforestation have been recorded since the 1960s, much of which took place in the lowland parts (the *terai* and inner *terai* of the Sivalik mountains). In particular, the hill and middle mountains experienced negligible deforestation since the mid-60s. This regional pattern is typically explained by the opening of Nepal to the outside world in 1951, and subsequent foreign aid projects of the 1950s and 60s that successfully suppressed malaria in the lower regions, and patterns of migration from the middle mountains into the *terai.*

More sophisticated variants of the population hypothesis recognize the possibility of a reverse causation from environmental degradation to population size: with shrinking resources families are induced to increase fertility in order to augment family labor stocks valuable in collection activities, as well as in conversion of forests to cultivation (Nerlove (1991), Dasgupta (1993, 1997), Dasgupta and Maler (1997), Maler (1998)). If valid, it could give rise to a population-environment degradation vicious circle. The reverse link is empirically investigated in the context of Nepal by Filmer and Pritchett (1996) using the LSMS data, and actually find the contrary evidence: firewood and water scarcity (measured by time taken to collect one unit of the corresponding resource) have a small, statistically significant negative effect on fertility.

Property Rights and Local Collective Action

Historical accounts of the ecology of colonial societies typically focus on the role of the colonial state in appropriating common forests for the use of the state, large-scale privatization of forest land for commercial purposes, the consequent decline of communal rights, and conversion of communal property resources to open access resources (Guha (1989), Metz (1991), Chakravarty-Kaul (1992, 1996), Gadgil and Guha (1992)). Critiques of the poverty-environment and population-environment hypotheses have been advanced along these lines by Ostrom (1990), Somanathan (1991) and Jodha (1997), on the basis of numerous empirical and institutional case studies. It is argued that traditional communities maintained environmental resource balance as a result of (i) the great dependence of their livelihood on local natural resources, and their explicit realization of the link between the resource base and their own livelihoods; (ii) the relative isolation and small size of these communities, (iii) existence of local self-regulation and communal investments in the local resource base, and (iv) enforcement of these regulations via social sanctions, group action and sometimes feudal land arrangements. All of these came to be eroded by a variety of market pressures and state interventions in the last two centuries. Administrative, physical and market integration reduced dependence of communities on the local resource base; takeover of ownership and control by a distant state removed local control and the benefits of local knowledge concerning the resource base, heightened insecurity of appropriability rights by local

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controlling for other factors. Moreover, they are subject to problems of identifying directions of causation, thus raising the serious problem of confusing causes with symptoms. In the context of Nepal, a frequently cited study by Kumar and Hotchkiss (1988) estimated that a 1% increase in deforestation increased fuelwood collection time for women by 0.6%. Based on this they estimated that the deforestation that occurred in Nepal between the early 1970s and the mid-1980s resulted in a 45% increase in total collection time by women, reducing their field labor input by 1.13 hours per day, and a total reduction of family labor per hectare of approximately 40% in high deforestation areas. In addition, they documented significant effects on child nutrition in poor families.

residents, and weakened enforcement of regulations --- all of which effectively converted CPRs to open access resources. In some cases state control was accompanied by large scale felling of trees for building railroads and government buildings, and by privatization , concessions or subsidies to private interests (particularly argued by Binswanger (1991) in the context of the Brazilian Amazon). These processes were begun to be reversed partially --- in India in the 1930s by the British with the creation of joint forest management councils that returned control to some local communities – and since the 1980s in Nepal with the creation of community forest user groups.

Most of these authors downgrade the importance of poverty or population pressure, except insofar as they affect the success of collective action among local communities in self-regulating resource use. Somanathan, for instance, explicitly argues in the context of the UP hills in India:

> ``The oft-repeated view that attributes deforestation mainly to population pressures…is misleading. Deforestation would occur even when population density is low if no system of control of forest use by settled communities existed. It did occur, in widening circles around villages within a few years (hardly enough time for a population explosion!) of traditional controls being disturbed in the 1920s. And deforestation does not occur even when population density is high, provided a control system exists, as is demonstrated by the densely populated valley below the bare Chandag Reserve with its well-protected panchayat forests. The decisive factor has always been presence of community control.'' [11]

Apart from formal property rights, the role of community characteristics that affect informal collective action has been stressed by a large literature (Ostrom (1990), the Fall 1993 symposium on Management of Local Commons in the *Journal of Economic Perspectives,* Baland and Platteau (1996), Bardhan and Dayton-Johnson (1997), Bardhan (2000)). These include the size and heterogeneity of the community in question with respect to socio-economic characteristics. The traditional presumption is that larger and more heterogenous communities are characterized by lower capacity for effective collective action. Varughese and Ostrom (2001) study 18 Nepalese villages in the middle-hill areas, where they measure collective action by the existence of formal or informal rules regulating entry and harvesting in forests, monitoring of entry and harvesting, and communal forest-related investment activities. They find that collective action (categorized into low, medium and high categories) is strongly associated with the forest stock condition (as assessed by forestry specialists). However, they do not find evidence for any significant association with measures of socio-economic heterogeneity within the community (of either location, wealth, ethnicity or caste). Agarwal and Yadama (1997) study 279 UP villages in Kumaon district in northern India, where variations in local forest conditions (as assessed by local villagers) are explained by population pressure (land per household), market pressure (proxied by distance to paved roads), besides the existence and functioning of forest user groups (as measured by size and age of the group, number of meetings held, and whether forest guards were hired) . Moreover, the formation and functioning of these user groups appears to be responsive to the existence of resource scarcities that emerge as a result of demographic and market pressures. Interestingly, larger size tends to enhance the effectiveness of the user groups, contrary to traditional expectations. Agarwal and Goyal (1997) pursue the group size issue further in a sample of 21 UP villages, where they find that medium sized villages are the most successful with respect to collective action. They explain this in terms of lumpiness of the monitoring technology (e.g., hiring of forest guards) which offsets the traditional Olsonian effect.

The role of community forest groups in Nepal has been investigated by Edmonds (2000a), using the 1995-96 Living Standards survey for the Arun Valley, covering three districts in Eastern Nepal that came under the Nepal-United Kingdom Community Forestry Project (NUKCFP). This project created community forest user groups who were granted autonomy over management of local forests, with explicit programs of taxes and regulations, monitoring and investment. Owing to bureaucratic delays in implementation, less than 10% of all forest land had been transferred under this program by 1999. Edmonds finds a robust 10-12% reduction in firewood collection at the household level, irrespective of whether the forest user groups are treated as exogenous or endogenous, and whether other household and community factors (such as demographics, wealth, village infrastructure and forest stock measures) are controlled for. Edmonds (2000b) shows that the effect of the forest user groups varies substantially with the type and source of external development assistance in different parts of Nepal.

[11] Somanathan (1991, p. PE-44)

Modernization: Commercialization, Agricultural Intensification

The role of increasing market integration and commercialization of local communities, changes in agricultural technology that raised agricultural productivity, and of land reforms and land reclamation programs that intensified agricultural operations and caused conversion of forest lands to agricultural land, have been stressed by a number of authors, such as Jodha (1980, 1985, 1986), Leach and Mearns (1988) and Hansen (1993). Foster, Rosenzweig and Behrman (1999) find that increased agricultural productivity associated with the Green Revolution in India between 1970 and 1982 drove up land rents and caused significant conversions of forest land. Their study employs a panel data set covering 243 villages throughout India which uses satellite data to measure land use, and merge it with survey-based information on household incomes, consumption, size, population, agricultural productivity and industry presence. They find that a 30% increase in productivity reduces forested land by 64% and forest density by 70%, while adding a factory results in a 40% increase in forest area and 34% increase in forest density. Hence the nature of the growth process matters, rather than simply the rate of growth in incomes. They also find evidence suggesting that community forest management may emerge endogenously as a response to local deforestation.

Other adaptive mechanisms in the context of the process of commercialization and development are stressed by a number of authors in the Himalayan region. Using a simulation model, Bluffstone (1995) argues that the existence of off-farm labor markets in Nepal allows households in the *terai* to switch their time away from collecting firewood and fodder as a result of deforestation. Higher wages can cause households to switch to commercial fuels, though the size of the required wage increase to contribute to such an energy transition appears to be quite large. In contrast in the hill regions where off-farm labor markets are missing, animal-raising activities actually increase as a result of deforestation, thus intensifying the pace of deforestation. Amacher, Hyde and Kanel (1996) find significant elasticities of labor supply and fuelwood collection activities of Nepalese households with respect to shadow wages in the *terai,* though not in the hills. They also identify incentives for household to adopt improved stoves that conserve energy. Sarkar (1998) describes a case study in India's Himachal Pradesh where a number of countervailing effects of market integration are observed: diversification of farming into horticulture and availability of education and government service employment shifts occupational structure away away from traditional livestock practices, and availability of fertilizers and woodfuel substitutes reduces dependence on manure and firewood respectively. Clearly the effects of modernization are complex enough to resist simple generalizations.

3. MODEL

The model underlying our empirical work is a conventional one in the economics of the household. We outline its main features here (further details are available at http://econ.bu.edu/dilipm/wkpap.htm/nepalmod1.pdf). Since we are principally involved in explaining cross-sectional differences we ignore intertemporal issues and thus include a static representation of the behavior of households in different villages at a given point of time. We treat each household as a single unit: household i in village v maximizes a utility function of the form

(1) $U_{iv} = u(F_{iv},q_{iv},H_{iv},hs_{iv}) - m(F_{iv} - F_v/n_v)$

where F_{iv} denotes firewood collected by the household, q_{iv} denotes quantity of other goods consumed, H_{iv} denotes time devoted to household tasks, hs_{iv} denotes family size and composition. U is a utility function which is increasing in all these arguments. The household's welfare also depends on village norms concerning firewood collection, specifically on the deviation of its collection from the household village average collection F_v/n_v (with F_v denoting total collections in the village and n_v the number of households): this could either represent the present value of its future utility resulting from sanctions imposed by the rest of the village for excessive current consumption, or simply a pure peer effect in consumption.

Owing to data limitations we ignore the possible existence of firewood markets within the village. About one-tenths of the Nepal LSMS sample households purchase some firewood, and the smallness of this sample makes it difficult to study purchase-sale decisions with any accuracy. We therefore assume that firewood used must be entirely collected by the household itself, an assumption that is true for nine-tenths of the sample. In later work we hope to study purchase and sale behavior in more detail. This assumption also simplifies our modeling and estimation considerably.

A household can earn income by allocating family labor across the following occupations: (1) self-employment in agriculture or livestock, (2) wage labor in agriculture, (3) wage labor in non-agriculture, and (4) self-employment in nonagriculture. Besides this, time is allocated to schooling, household tasks and firewood collection.[12] The returns from different occupations depend on respective assets owned (land, nonfarm business assets, education), labor allocated, wage rates, besides the local productivity of agriculture and infrastructure available.

Each household takes prices of goods q, and the consumption patterns of others in the village as given. The costs of firewood collection depend on charges paid for a unit of firewood (which depends on the nature of formal and informal regulations effectively enforced in the village), and the time spent collecting a unit of firewood. The collection time in turn depends on the size, quality and proximity of the forest, and the collection activities of others:

(2) $T_{iv} = T + d(FS_v - F_v) + e_{iv}^1$

where FS_v denotes the historical forest stock endowment of the village, d is a negative parameter, T a constant and e_{iv}^1 is an idiosyncratic mean-zero household deviation from the village average collection time that depends on the exact location of the household within the village. (2) represents the key extraction externality across households: greater collection by others increases the time required to collect by any given household. While we are unable to observe the forest stocks, we are able to observe the unit collection times within the village, which effectively serves as a proxy for the unobserved forest stock. This method of overcoming the inability to measure forest stock or density accurately has been used earlier by Kumar and Hotchkiss (1988), and is argued by Amacher, Hyde and Kanel (1996) to yield a superior measure of fuelwood scarcity than forest stock data.

Household i in village v takes as given its own characteristics of asset ownership (A_{iv}) comprising land, nonfarm assets, education, occupation, family size and composition; its firewood collection time (T_{iv}), and village parameters consisting of village average collection level F_v/n_v and local prices, wages, infrastructure, technology etc. all of which are represented by the vector V_v. The household maximizes its utility subject to a relevant budget constraint (postulating that its incomes cannot exceed expenditures) and a time allocation constraint. This generates a behavioral equation for firewood collection level which is a best response to the collection activities of others in the village (the interdependence arises both through consumption norms and the collection externality effect). This involves equating the marginal utility of fuelwood with the marginal cost of collection. The best response equation takes the form

(3) $F_{iv} = b_1 + b_2Y_{iv} + b_3\ hs_{iv} + b_4p_v + b_6\ F_v/n_v + b_7\ c_v + b_8\ T_{iv} + b_9\ T_{iv}L_{iv} + b_{10}(T_{iv})^2 + e_{iv}^2$

upon taking a suitable Taylor approximation, where Y_{iv} denotes household income, p_v relevant local prices, c_v is a collection charge paid per unit collected, L_{iv} is labor time available for firewood collection and other household tasks, and e_{iv}^2 is a household specific error term. Here household income and available labor time are chosen by the household and so do not represent parameters exogenous to the household. These are in turn functions of household attributes A_{iv} and village characteristics V_v, thus permitting the best response equation to be modified to

(4) $F_{iv} = a_1 + a_2A_{iv} + a_3\ hs_{iv} + a_4p_v + a_6\ F_v/n_v + a_7\ c_v + a_8\ T_{iv} + a_9\ T_{iv}A_{iv} + a_{10}(T_{iv})^2 + e_{iv}^2$

The theory predicts the following signs for parameters of this equation: a_2 with respect to wealth is ambiguous owing to contrasting income and substitution effects (e.g., higher land owned raises the value of time spent on the farm rather than collecting firewood, but also raises income and consumption levels in general); with respect to occupation and education we expect to be negative as the family shifts away from livestock and into nonagricultural occupations; a_3 the effect of family labor stock is expected to be positive; a_4 negative or positive depending on whether the commodity in question is a complement or substitute to fuelwood (besides supply-side and income effects if the household happens to

[12] Households tend to collect their own firewood, rather than engage hired labor for this purpose. Somewhat surprisingly, even wealthy households with full-time domestic servants do not rely on these servants for collection. So we treat collection activities as carried out by family members themselves.

be a net producer of that good), a_6 is ambiguous owing to contrasting peer (positive) and collection externality (negative) effects; a_7, a_8 and a_9 are expected to be negative by raising collection costs.

A Nash equilibrium of this game is one where each household is playing a best response to the collection activities of other households in the village. The best response equation implies that the village average collection will be a function of the village averages of the household attributes entering that equation, besides the village attributes that enter that equation as well. Accordingly the best response equation can be directly estimated from observed household collections. Alternatively, the equilibrium equation can be estimated by substituting for the village average collection F_v/n_v the corresponding village averages of the household attributes. We thus end up with an estimable equation of the form expressing household collections as a function of household and village attributes:

(5) $F_{iv} = r_1 + r_2A_{iv} + r_3\, hs_{iv} + r_8\, T_{iv} + r_9\, T_{iv}A_{iv} + r_{10}\, (T_{iv})^2 + r_4W_v + e_{iv}$[3]

where W_v is a vector of village variables that include local prices, wage rates, collection charges, agricultural productivity and means of all relevant household attributes (asset ownership, demographics, collection times) that directly impact household collection incentives through (4). Expected signs of coefficients in (5) are analogous to those in (4), under the natural stability condition that a_6 is less than one. W_v appears as a village-specific (random) effect in the regression. Our empirical strategy will be to first estimate regression (5) at the level of the household, treating W_v as a village-specific effect, and then subsequently explore the determinants of the village effect W_v.

The preceding formulation of equilibrium collection behavior takes as given the nature of prevailing regulations of either formal or informal nature concerning firewood use which determine collection charges, i.e., whether the local forests are effectively open access or regulated. At the next level, these are determined by the nature of property rights prevailing (i.e, whether or not local forest user groups exist), and local institutions of collective action (which depend on measures of size (village population n_v) and heterogeneity of the local community with respect to asset ownership, collection times and social (ethnic, caste or religious) fragmentation. Collection charges are not well-measured in the Nepal LSMS, so we shall use these determinants of collective action and property rights as proxies.

Equilibrium prices and wages will also be endogenous at the village level, and will depend on the distribution of relevant household attributes, besides village infrastructure and geography. Accordingly, the regression explaining the village effects will take the following form:

(6) $W_v = f_1 + f_2A_v + f_3D_v + f_4DFUG_v + f_5CA_v + f_6T_v + f_7p_v + f_8Ap_v + f_9O_v + f_{10}L_v + u_v$

where A_v is a vector of means and variances of asset ownership that impact on collections at the local level, D_v is a vector of demographic variables (such as population size and composition across age, sex and ethnic categories), $DFUG_v$ is a dummy variable representing whether or not a local forest user group exists, CA_v is a vector of village attributes such as social fragmentation, wealth inequality and heterogeneity with respect to collection times that affect informal collective action within the village, T_v is mean and variance of collection times, p_v is a vector of relevant prices of goods that are complements or substitutes for fuelwood, Ap_v is a vector of variables representing agricultural productivity, O_v represents occupational structure, and L_v measures of location and geography that directly utility or costs of fuelwood collections. Since nonagricultural occupations make less demand on natural resources than agricultural ones, and farming less so than livestock rearing (an activity complementary to firewood collection), O_v includes the fraction of village labor devoted to nonagricultural occupations, as well as livestock ownership per household. L_v would include geographical factors such as elevation that directly affect the need for fuel for heating purposes, and proximity to markets and roads that affect the extent of market integration and availability of fuel substitutes.

4. DATA

The Nepal LSMS data we use concerns 215 rural wards, with approximately 12 households per ward, yielding a total of around 2700 households. Firewood collection is measured in baskets (bharis) of firewood collected by the household in one month. Table 1 provides descriptive statistics for household characteristics, and Table 2 for village

Table 1: Household Characteristics: Descriptive Statistics[13]

Variable	No of OBS	No of ZEROS	MEAN	STD. DEV.	MIN	MAX
N_FIREC	2671	807	5.79	5.77	0.00	35.00
TOTCONS	2713	0	0.04	0.03	0.00	0.45
V_C_LAND	2349	685	0.15	0.59	0.00	17.5
NF_BUS	2713	2261	0.00	0.07	0.00	2.5
CUL_LAND	2349	684	0.55	1.14	0.00	14.22
APGHC1	2713	1478	0.14	0.19	0.00	0.89
FWAG_H	2674	1590	0.16	0.25	0.00	1.00
FWNAG_H	2674	1705	0.11	0.20	0.00	1.00
FNAG_H	2674	2072	0.08	0.21	0.00	1.00
ET_CFIRE	2335	0	5.08	2.89	0.17	25.02
N-COW	2440	241	3.72	3.12	0.00	27.00
N_FAM2	2713	25	4.41	2.06	0.00	20.40
EDU_HEAD	2713	1913	1.87	3.38	0.00	17.00
D_MIG1	2713	2189	0.19	0.39	0.00	1.00
D_HWOM	2713	2362	0.13	0.34	0.00	1.00
MID_ETH	2711	1963	0.28	0.45	0.00	1.00
OTH_ETH	2711	1992	0.27	0.44	0.00	1.00
BUD	2711	2536	0.06	0.25	0.00	1.00
MUSLIM	2711	2615	0.04	0.18	0.00	1.00
REL_OTH	2711	2681	0.01	0.10	0.00	1.00

Table 2: Village Characteristics: Descriptive Statistics

Variable	No of Obs	No of Zeros	St. Dev.	Mean	Min	Max
Wealth, Inequality, Poverty						
MTOTCON	215	0	0.013783	0.035623	0.01147	0.099124
GINICONS	215	0	0.09	0.30	0.09	0.66
APGC1	215	19	0.11	0.13	0.00	0.48
Population Pressure						
POP_WARD	215	0	0.889	0.797	0.042	5.875
N_NFAM2	215	0	0.72	4.39	2.76	6.64
Forest User Groups						
DFUG3	215	125	0.49	0.42	0.00	1.00
FR_FUG3	215	125	0.19	0.11	0.00	0.92

[13] Consumption, asset values and agricultural productivity in Tables 1 and 2 are expressed in Rupees million. Population numbers are in thousands of individuals. Elevation is expressed as kilometers above sea level. Distance variables are expressed in hours taken to travel.

Collective Action:

Measures

N_USER3	215	153	0.71	0.35	0.00	4.00
FR_USER3	215	163	0.73	0.22	0.00	6.82
FR_INFORMATION	215	91	0.23	0.17	0.00	1.00
C_INFORM	215	91	0.50	0.58	0.00	1.00
C_IRRIG	215	101	0.50	0.53	0.00	1.00
C_CREDIT	215	192	0.31	0.11	0.00	1.00

Determinants

GINICUL	208	0	0.14	0.64	0.27	0.92
FRA_ETH	215	52	0.24	0.33	0.00	0.74
FRA_REL	215	119	0.19	0.14	0.00	0.75
SETCFIRE	185	9	0.88	1.50	0.00	5.95

Forest Stock

M_ETCFIR	185	0	2.41	5.09	0.50	12.40

Modernization:

Occupational Structure

FR_NAG	215	42	0.12	0.08	0.00	0.85
AV_COW	215	0	1.67	3.62	0.40	9.10

Education

MEDUHD	215	17	1.46	1.88	0.00	7.08

Agricultural Productivity

AVFPR	208	0	0.22	0.16	0.01	1.69

Infrastructure

T_DIRT1	208	0	12.99	6.20	0.02	84.00
T_DIRT2	211	0	2.43	0.89	0.02	22.00
T_MARKET	215	0	7.43	4.21	0.10	61.09
T_PAVED	205	0	13.05	8.03	0.06	84.00
AGR_EXT	204	157	0.42	0.23	0.00	1.00
P_CANAL	206	174	0.36	0.16	0.00	1.00
TUBE	206	201	0.15	0.02	0.00	1.00
T_KRISHI	215	0	4.23	3.21	0.13	25.62
T_PRIM	215	0	0.41	0.43	0.07	4.01
T_HEALTH	215	0	1.24	1.31	0.07	7.79
T_BUS	206	0	11.33	6.07	0.07	78.55
T_BANK	215	0	5.52	3.80	0.11	42.42
T_NEAR	215	0	5.29	4.87	0.14	29.55
T_SHOP	215	0	1.20	0.78	0.03	9.42
AVE_ELE	193	156	6.81	2.89	0.00	24.00

Geography

ELEV	215	0	0.94492	0.93845	0.05800	5.29
LAT	215	0	0.84	27.69	26.42	29.75
LONG1	215	0	2.13	84.68	80.25	88.08
AM_RAIN1	206	131	0.48	0.36	0.00	1.00
AM_RAIN2	206	93	0.50	0.55	0.00	1.00
D_DISAS	196	87	0.50	0.56	0.00	1.00

characteristics in the sample. Firewood collections (**n_firec**) average 5.8 bharis per month, with considerable variation around this mean (the coefficient of variation is approximately one). As will become evident, most households collect between 4 and 9 bharis. Mean household annual consumption (**totcons**) is about Rs 40,000, while average family size in adult equivalent units (**n_fam2**) is 4.4, implying an annual per capita consumption of the order of US$250. The average poverty gap **apghc1** (relative to a poverty line of $1 per day per capita) is 14%, while that relative to $1.50 per day is 43%, indicating high levels of poverty. The average fraction of family labor time allocated to wage labor in agriculture (**fwag_h**) is 16% and in nonagriculture (**fwnag_h**) is 11%, to self employed labor in nonagriculture (**fnag_h**) is 8%, with the residual 65% allocated to self-employment in agriculture. The average number of cows owned per household (**n_cow**) is 3.7. Hence the sample consists primarily of farming and livestock based occupations. Principal assets consist of cultivated land (**cul_land** in hectares, and **v_c_land** in values), livestock and nonfarm business assets (**nf_bus**). Education levels are low: 70% of heads of households have no education, and their average number of years of schooling (**edu_head**) is 1.87. 13% of the households are headed by women (**d_hwom**=1). In terms of religion, the households are predominantly Hindu: only 6% are Buddhists (**bud**=1), 4% is Muslim (**muslim**=1) and 1% belong to other religions (**rel_oth**=1). 45% belong to upper castes (Brahmin or Chhetry), 28% to middle castes (magar, thuru, newar, tamang, rai, gurung, limbu) (**mid_eth** =1), 27% to Muslims and lower castes kami, damai and surki (**oth_eth** =1). 19% of the households reported migrating into the village (**d_mig1=**1) for non-economic reasons within the current and previous generation.

Table 2 lists village characteristics, grouped into the different categories impacting on firewood collection incentives:

(1) *Wealth, Inequality and Poverty:* mean household annual consumption (**mtotcons**) in Rs. million, its Gini coefficient (**ginicons**), and the average poverty gap in the village (consumption per capita relative to $1 a day) (**apgc1**).

(2) *Population Pressure:* village population (**pop_ward**) in thousands of persons, and mean household size (**m_nfam2**). An average village has eight hundred residents, with a mean household size of 4.4, implying existence of about 175 households.

(3) *Forest User Groups:* **dfug3** is the fraction of villages where at least one household reported collecting firewood or fodder from a community forest, and **fr_fug3** is the corresponding fraction of households. We use the household rather than the community questionnaire for this purpose, owing to its greater reliability in this respect. On average two out of five villages have user groups, and one tenth of the households are in such groups.

(4) *Collective Action:* is not easy to measure precisely, so we use a number of different proxies. These include the number (**n_user3**) and fraction (**fr_user3**) of sample households belonging to either a farmer, water or women's group, as reported in the community questionnaire. Other measures are constructed from the household questionnaire: dummies **c_credit** for existence of a credit group (borrowing from a Grameen Bank type of institution, or a local credit group (*Dhukuti)),* **c_irrig** for existence of a water group (if at least one person in the village uses an irrigation system managed by the community). The dummy **c_inform** denotes the existence of either a credit or irrigation group as defined above, while **fr_info** is the fraction of households who reported belonging to such groups. Note that these groups pertain to management of resources other than firewood, so these represent auxiliary measures of the extent of informal collective action generally prevailing in the village, rather than specifically for the purpose of regulating firewood or fodder use. The LSMS does not make available any information concerning local informal regulation of forest use. Going by the household responses which may be expected to be more accurate, about half of all villages have an informal (non-forest) group, and these tend to be primarily irrigation rather than credit groups. And 17% of households are organized into such groups. We have no data concerning the effectiveness of these groups. Determinants of existence and effectiveness of informal collective action include measures of socio-economic inequality and heterogeneity: **ginicul**, the Gini coefficient of cultivable land owned in the village, fragmentation indices with respect to caste (**fra_eth**) and religion (**fra_rel**) which equal 1 minus the probability that any two randomly selected households in the sample will belong to the same group, and **setcfir**, the standard deviation of firewood collection time within the sample. In addition, collective action may depend on wealth inequality, poverty, village population, village infrastructure and

remoteness[14], development efforts by the government or nongovernmental groups (NGOs), and the nature of the resource situation in question.

(5) *Forest Stock,* proxied by average collection time in the village (**m_etcfir**). The average collection time per bhari is over 5 hours, implying that on average households devote 25-30 hours per month in collection activities.

(6) *Modernization,* includes a host of different factors: *Occupational Structure,* the importance of livestock and nonagricultural occupations, represented respectively by **av_cow**, average number of cows per household in the village, and **fr_nag**, the average fraction of household labor time allocated to nonagricultural occupations; *Education*, represented by **meduhd**, the average number of years of schooling of heads of households in the sample; *Agricultural Productivity* represented by **avfpr**, average price of cultivable land in the village (in Rs. Million); and *Infrastructure*, including dummies for whether an agricultural extension worker visited in the past 12 months (**agr_ext**), existence of irrigation canal (**p_canal**) or tubewell (**tube**); average hours of electricity per week (**ave_ele**), average time in travelling to a vehicle passable dirt road (**t_dirt1**), a vehicle impassable dirt road (**t_dirt2**) , paved road (**t_paved**), market center (**t_market**), local shop (**t_shop**), bus stop (**t_bus**), police station (**t_prim**), health center (**t_health**), bank branch (**t_bank**), nearest city (**t_near**), agricultural (Krishi) center (**t_krishi**). The remoteness of these villages is revealed by the fact that the average times to travel to vehicle passable roads, markets, bus stops, bank branches or towns exceed 4 hours; and there is about two hours of electricity supplied per day. Between one sixth and a quarter have agricultural extension services and canals

(7) Geography, including elevation above sea level in kilometres (**elev**), latitude (**lat**), longitude (**long1**), and **d_disas**, whether a natural disaster occurred in the previous 5 years. There is relatively little variation in latitude and longitude, and greater variability in elevation, which more directly captures differences in climate and terrain, so elevation will be used as the primary geographic variable.

Note the significant cross-village variation (with coefficient of variation in the vicinity or exceeding unity) in the poverty, population, forest user groups, informal collective groups, social fragmentation, importance of nonagricultural occupations, most infrastructural facilities, and aspects of geography (elevation and proneness to natural disaster). It is this wide variability of village attributes that creates the hope of estimating their respective roles with some precision.

5. EMPIRICAL METHODOLOGY

Our modeling approach has a number of advantages, both from the standpoint of econometric method and economic interpretation. Many previous studies rely solely on a version of the village equation (6), where many of the right hand side variables are endogenous. Take for instance an attempt to estimate the effect of village poverty on firewood collection: poverty may be an effect and not just a cause of high firewood collection levels, as the more sophisticated variants of the poverty-environment hypothesis postulate. Similar endogeneity problems arise with respect to most of the other variables on the right hand side of this equation: high population size, the formation of forest user groups, local collective action, high mean collection time, high prices of wood related products and occupational structure may all be effects rather than causes of deforestation. The error term u_v would then be correlated with the right-hand-side variables of (6), rendering least squares estimates biased and inconsistent. Endogeneity of household variables will also need to be tackled.

Indeed, the existence of these endogeneity issues is interesting of its own right, as they help identify the existence of reverse causal links from deforestation to poverty or population size. Accordingly the existence and magnitude of the reverse links postulated by the more sophisticated versions of the poverty-environment and population-environment hypotheses can potentially be tested (they will be reported in future versions of the paper).

[14] For instance, Bardhan (2000) finds irrigation user groups in the Southern Indian state of Tamil Nadu to depend on how well connected the village is with urban centers (which presumably affects exit options of village members), apart from inequality and heterogeneity.

Further econometric problems arise from the fact that many of the variables appearing on either side of equations (5) and (6) are censored or discrete. For instance, the vast majority of Nepalese households are poor, who do not own productive assets such as land, nonfarm businesses or education, so measures of asset ownership are frequently zero. Most importantly, a significant fraction of households (between one fifth and one sixth) in our data do not use firewood at all, mostly residing in the *terai* where fuel alternative exist. Since the `energy transition' from traditional to modern fuel sources is of key importance, it is necessary to model and estimate how households might switch from firewood to alternative sources. And ignoring these `corner solutions' lead to biased estimates of parameters. Equation (5) must therefore be modified to

(5') $F_{iv} = \text{Max}\,(0, r_1 + r_2 A_{iv} + r_3\, hs_{iv} + r_8\, T_{iv} + r_9\, T_{iv}A_{iv} + r_{10}\,(T_{iv})^2 + r_4 W_v + e_{iv}^3)$

In a compact way, eq. (5') may be written as

(5'') $F_{iv} = \text{Max}(0, F_{iv}^*)$, where

F_{iv}^* denotes $r_1 + X_{iv}\, b + r_4\, W_v + e_{iv}^3$, vector b denotes $(r_2 , r_3 , r_8 , r_9 , r_{10})$ and X_{iv} denotes $(A_{iv} , hs_{iv} , T_{iv} , T_{iv}\, A_{iv} , (T_{iv})^2)$. Using (6), W_v can be written compactly as

(6') $W_v = Z_v\, f_1 + u_v$

Hence the estimable equation (5'') can be written as

(7) $F_{iv} = \text{Max}(0, F_{iv}^*) \equiv \text{Max}(0, r_1 + X_{iv}\, b + Z_v\, f_2 + u_v + e_{iv}^3)$

The latent variable F_{iv}^* can be expressed as the sum of terms explained by observed household characteristics X_{iv} and observed village characteristics Z_v besides corresponding unobserved error components e_{iv}^3 and u_v. Note that this can be viewed as a panel data set, with a common village effect applying to each set of households from the same village. However, the common village effect $Z_v\, f_2 + u_v$ is a random rather than a fixed effect. In addition, it is not legitimate to assume that the random effect is uncorrelated with household characteristics X_{iv} , as is commonly assumed in conventional panel data estimation methods for random effects models. For instance, villages endowed with a favorable climate and soil conditions are likely to be more prosperous, so households in such villages may be expected to accumulate more assets and have higher living standards. Accordingly, we must explicitly allow for correlations between the random village effect and household characteristics.

An additional source of bias in attempting to estimate the coefficient vector b by applying ordinary least squares to predicting F_{iv}^* on the basis of household characteristics X_{iv} arises from the potential correlation between X_{iv} and unobserved household-specific error e_{iv}^3. For instance, certain unobserved household traits (such as intelligence or ability to work hard) that vary across households within a village may both affect household asset accumulation, consumption levels, occupation choices as well as firewood collections. In other words, household living standards, occupations or asset levels may be the consequence rather than cause of firewood collection behavior (or other unobserved traits that cause both sets of variables).

Our econometric approach addresses these various sources of potential bias. Our strategy is roughly the following (further details are available in the Appendix). To overcome the potential correlation between observed and unobserved household characteristics, we use instrumental variables (i.e., other household variables that are exogenous to the household's behavior, i.e., uncorrelated with e_{iv}^3, but those that determine observed household characteristics X_{iv}). Examples of such instruments are land inherited by the household, education and occupation of parents of the head of household, the age and gender of head of household , and the location of the household. These represent exogenous random shocks that affect wealth, occupation, education and fertility choices; accordingly they help identify the effects of these variables on firewood collection.

These instruments may however be correlated with village characteristics: remote villages with poorer infrastructural facilities will generally affect assets, occupation and education of current as well as preceding generations. To get around this in the estimation of b, we can try to wash out the common village effects, by studying how variations across households within the same village with respect to firewood collection are explained by corresponding variations in their observed characteristics (appropriately instrumented). This is feasible, however, only if the latent variable F_{iv}^* is observable for all households, which it is not. Intuitively, the problem is that the model (5”) is not linear, so we cannot use a strategy of taking first differences to filter out the effect of the common village effect. We get around this using Honore's (1992) estimator for censored panel data, explained further in the Appendix, to obtain a consistent estimate of the parameter b.

Having obtained the estimate of b, the effects of household characteristics, we move to a second stage where we estimate coefficients with respect to village characteristics (r_1 and f_2) using the residuals from the first stage, and regress these on the village variables (relevant details of this are also in the Appendix). At this second stage, the village endogenous variables are predicted using instruments at the village level. Measures of village geography or infrastructure that are unlikely to directly affect household costs and benefits of firewood collections, but likely to affect village poverty, population size, occupational structure, collective action or relevant prices are used as instruments. These include proximity to banks, post offices, health or school facilities, availability of canals or tubewells. Of course these could be correlated with other geography or infrastructure variables in L_v in eq. (6) that directly affect the costs and benefits of firewood collection. For instance, remote villages located at high elevations may rely more on forest wood owing to a colder climate and lack of commercial fuel substitutes, and such villages may be expected to have poorer infrastructure. The key point, however, is that as long as the geography and infrastructure variables that directly affect firewood demand are all included as explanatory variables in the regression, the instruments are valid (since all that is needed is that they be uncorrelated with the error term u_v in (6), *conditional* on the included L_v variables).

Our two step estimation approach allows us to identify direct and indirect effects of various factors on collection incentives. For instance, the poverty-environment hypothesis stresses the direct positive effect of a household’s poverty on its collection incentive (relative to non poor households), which aggregated at the level of the village implies that the village wealth distribution affects village level collections. This effect is identified by the coefficient of wealth variables in the household level equation (5). The property rights/collective action hypothesis argues instead that distributional effects matter only insofar as they affect community control, an effect which would show up in the village level regression (7) . Hence the relative significance of the poverty variables in the two regressions helps discriminate between the respective hypotheses. Similar comments apply to other factors such as population size, occupational structure or locational heterogeneity.

6. RESULTS

Living Standards Determinants

Table 3 presents regressions predicting household consumption on the basis of household characteristics, with village fixed effects. The first column treats all household characteristics as exogenous, while the second column treats household assets (land, nonfarm business assets, education, livestock), occupation and family size as endogenous. These are predicted by the following set of instruments: value of land inherited; poverty, education and occupation of parents of head of household; age and sex of head of household, and whether the family migrated into the village for non-economic reasons, besides the set of included exogenous characteristics.[15] As expected, land and nonfarm business assets are statistically significant, but their elasticities are small, between 0.01-0.02. Hence neither of them individually or in combination are reliable measures of living standards; for this reason (and the fact that asset ownership affects occupational choices as well) we shall henceforth use household consumption as a proxy for household wealth. Occupation and education effects on living standards are weak, except that those employed as wage

[15]The first stage predictions of endogenous variables incorporate the limited dependent nature of some of them, and are estimated using village fixed effects. Since asset ownership and occupational variables take many zero values, we use a panel censored regression for v_c_land, nf_bus, fwag_h, fwnag_h, and fnag_h. A panel GMM regression is used to predict n_fam2, and a panel Poisson count regression is used to predict n_cow and edu_head.

Table 3: Sources of Interhousehold Variation in Consumption[16]

	OLS ELASTICITY	2SLS ELASTICITY
Land (V_C_LAND)	**0.01***** (7.77)	**0.02***** (8.65)
NonfarmBusiness Assets (NF_BUS)	**0.01***** (3.63)	**0.02***** (3.45)
Wage Labor-Agri (FWAG_H)	**-0.31***** (4.14)	**-1.00***** (10.09)
Wage Labor-Nonagri (FWNAG_H)	**0.20***** (5.23)	**-0.17**** (1.98)
Self Employed-Nonagri (FNAG_H)	**0.39***** (3.17)	**-0.23** (1.20)
Cows Owned (N_COW)	**0.15***** (12.80)	**0.02** (0.63)
Household Size (N_FAM2)	**0.84***** (34.79)	**0.08** (1.35)
Education of Head (EDU_HEAD)	**-0.11***** (3.21)	**-0.08***** (4.62)
Fraction Child Labor (FRA_CHI)	**-0.58**** (2.54)	**1.55***** (7.11)
Fraction Male Labor (FRA_MALE)	**-0.52**** (2.11)	**1.52***** (6.95)
Fraction Female Labor (FRA_YWOM)	**-0.43*** (1.76)	**1.69***** (6.67)
Fraction Old Male Labor (FRA_OMAN)	**0.64**** (2.10)	**0.39**** (2.09)
Female Head Dummy (D_HWOM)	**-0.09***** (3.45)	**-0.35***** (6.15)
Mid-Caste Dummy (MID_ETH)	**-0.10***** (3.42)	**0.01** (0.33)
Low-Caste Dummy (LOW_ETH)	**-0.16***** (5.49)	**-0.06** (0.96)
Other-Dummy (OTH_ETH)	**-0.12***** (3.01)	**-0.08** (1.44)
Buddhist Dummy (BUD)	**0.13***** (3.66)	**0.21***** (3.17)
Muslim Dummy (MUSLIM)	**-0.02** (0.38)	**-0.11**** (2.04)
Other Religion Dummy (REL_OTH)	**0.04** (0.28)	**-0.00** (0.01)
n	**2217**	**1946**
R^2	**0.67**	**0.49**

[16] Absolute t-values in parentheses. *** denotes significant at 1%, ** denotes significant at 5%, * denotes significant at 10%. Elasticities with respect to dummy variables signify proportional change in consumption resulting from the dummy taking the value 1 rather than 0.

labor are significantly worse off, especially those in agriculture. The returns to education appear to be negative at the mean education of 1.87 years, which is low since most households have no education at all. Returns to education become positive only after 6 years of schooling. Households with a larger fraction of able-bodied and younger members are better off, presumably owing to their labor power. Buddhists are also better off than the rest whereas Muslims are somewhat worse off, and no other ethnic or religious attributes are significant. Female headed households are significantly worse off, by a factor of more than a third. Larger households are worse off, as the elasticity of total household consumption with respect to household size is close to 0.

Household Firewood Collection Regression

Table 4 presents estimates of b in the censored regression (7) predicting interhousehold variations in firewood collection with village fixed effects. More precisely, they show how predictions of the latent variable F_{iv}^* (which corresponds to actual collections when these happen to be positive) are affected by changes in household characteristics.[17] Estimates corresponding to treatment of all explanatory variables as exogenous are presented in the first set of columns. The remaining columns present estimates when consumption, poverty, occupation, livestock owned, family size and education are treated as endogenous, and predicted using the same set of instruments and limited dependent variable methods as in the consumption regression. Terms involving squares of certain variables (consumption, education of head, household size and firewood collection time) are included in the regression. The table reports derivatives (conditional on positive purchases) and elasticities with respect to these variables evaluated at the 30th, 50th, and 75th percentiles. The derivatives of nonlinear variables are evaluated at the median. Finally, the column labelled B*STD estimates the quantitative (as opposed to statistical) significance of each non dummy explanatory variable, by multiplying the estimated derivative by its standard deviation. It predicts the change in collections when collections are positive resulting from a standard deviation increase.[18] The width of the corresponding 95% confidence interval is noted in parentheses (more precisely, half the width, so with x in parentheses the confidence interval is the point prediction plus and minus x). For nonlinear variables, B*STD are reported at two values of the derivative B, evaluated respectively at the median and median plus standard deviation.

The most striking result concerns the evidence *against* the poverty-environment hypothesis. There is a strong positive relationship between consumption and firewood collection: wealthier households collect significantly more than poor households. The relationship becomes even stronger in the IV regression. And consumption is the dominant explanatory variable in terms of explaining variations in firewood collections in the sample, in terms of both statistical and quantitative significance. This pattern is confirmed by Figure 1, which plots collections against different percentiles of the consumption distribution in the regression sample. It creates 20 groups corresponding to the bottom 5%, the group between 5% and 10%, 10% and 15% and so on, of the consumption distribution, and for each group plots the mean and 95% confidence interval for mean firewood collections. Collections rise monotonically throughout the distribution (except for local downward movements across three sets of adjacent groups which are subsequently reversed), from a little over 4 bharis per household at the bottom end of the distribution, to over 9 bharis at the top end. Note also the width of the confidence interval changes little throughout the distribution, suggesting little heteroskedasticity.

Figure 1, however, does not adjust for differences in household size, and it may be argued that per capita consumption is a better measure of household wealth.[19] Accordingly Figure 2 redoes Figure 1, replacing percentiles of total consumption by percentiles of per capita consumption. While the upward relationship is somewhat attenuated, there is still no tendency for the poor to collect more than the rest of the population. There is a declining tendency over the first eight groups (i.e., going from the bottom 5% group which collects an average of slightly over 6 bharis, down to the ninth group between 40-45% of the consumption distribution which collects almost exactly 6 bharis). But beyond this the relationship is positive, with average collections rising steadily till the 17th group (between 80 and 85 percentiles) which collects almost 10 bharis, after which there is a slight decline with collections to over 8 bharis, greater than

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[17] This regression is formulated in levels, since the number of bharis collected is a discrete variable, taking many zero values, and moreover its range of variation does not appear very large (or exhibit heteroskedasticity).
[18] When censoring matters or the variable enters in a nonlinear way, the corresponding predictions will differ. Predictions that take these into account will be presented later.
[19] This criticism does not apply to the household regression, however, since it controls for household size explicitly as an explanatory variable in the regression.

among the bottom 80% of the distribution. The wealthiest groups collect more on average than the rest of the population (e.g., this results if we classify the population into five groups containing 20% of households each).

Figures 3 and 4 show that these results are not affected by the sample selection forced by missing values of certain variables used in the regression: they plot the same figures for the entire sample of over 2700 households rather than the regression sample. The lack of evidence in favor of the poverty-environment hypothesis is thus not the result of a sample selection bias induced by missing values of certain variables.

Note also there is no inconsistency here with results in previous literature, which document the significant role of firewood and other common property resources in the livelihoods of the poor. Most studies estimate dependence on these resources as a fraction of consumption expenditure (using some method to value the resources), and emerge with numbers varying between 15 and 25%; moreover, these are sometimes shown to be higher among poor households compared with nonpoor households. For one, these studies rarely control for other household characteristics that may be correlated with poverty, or control for endogeneity biases. But even apart from such biases, it is perfectly possible that firewood collections be increasing with consumption level, while at the same time the *proportion* of collections to consumption falls. This requires the elasticity of collections with regard to consumption to be less than unity, which is what we find for most of the distribution (e.g., at both the median and the 75th percentile). Yet what really matters when assessing the direct (partial equilibrium) effects of changes in inequality or poverty (i.e., abstracting from possible effects at the level of the village, operating through changes in collective action, occupational structure or prices) on total village collections is the behavior of the absolute level of collections with respect to consumption, rather than of the proportion. The behavior exhibited by the proportion is relevant instead in assessing the effects (rather than causes) of deforestation on different categories of households.

Given the remoteness and consequent absence of fuelwood substitutes in many of the villages, it is not surprising to see the substitution effects dominated by the corresponding income effects. Wealthier households would be expected to consume more food, live in bigger houses and thus demand more energy. This also accounts for the inflexibility of collections with respect to collection times: despite the wide variation in hours need to collect one *bhari* (between one and 8 hours), there is virtually no effect on the amount collected. Clearly, firewood fills a basic need with very little scope for substitutability. In turn this implies that shrinking forests that increase collection times lead households to adjust by increasing total time spent collecting the firewood, a result consistent with (and even sharper than) the results of Kumar and Hotchkiss (1988) which dealt with a different (earlier) dataset.[20] It is remarkable that this is just as true for wealthy and poor households: there was no significant interaction effect between consumption level and collection time.[21] One might have expected wealthy households to rely more on purchases or hired labor, but they seem to be devoting just as much time in collecting firewood themselves, despite the higher shadow cost of their time. The inflexibility suggests the absence of one possible stabilizing factor in the deforestation process (wherein households react to shrinking forests by cutting back on their collections).

Occupation choices have a weak effect, along the lines one might expect: the non-IV regression predicts livestock to have a significant positive association with collections, and nonagricultural occupations have a significant negative association. The IV results show only self-employment in nonagriculture to have a statistically significant effect. In terms of quantitative significance, this variable as well as livestock ownership have modest effects, with a standard deviation change in either of these changing collections by half a bhari. It is somewhat surprising to see the large quantitative significance of the education variable in the IV results, where the predicted effect of a one standard deviation change outweigh even the effect of a corresponding change in total consumption. However, these effects are imprecisely estimated, represented by the correspondingly large prediction standard errors.

The only other statistically significant variable in the IV regression is the fraction of family labor contributed by young females in the households, consistent with the notion that they are the principal collectors of firewood within the household. In importance they are followed by young males, and children, with old members being the least important. Ethnicity or religion seems to make little difference. Female headed households collect less, presumably owing to the involvement of the female head in managing the household which leaves less time for collection (any indirect effects

[20] They estimated that a 10% increase in collection time reduces collection levels by 3%, and total collection time by 6%.
[21] This interaction effect turned out to be insignificant so is not reported in Table 4.

via poverty being already incorporated elsewhere in the regression). Household size by itself also seems to have little effect, controlling for family well-being, occupation and education --- reinforcing the notion of an inelastic demand for energy at the level of the household for cooking or heating purposes that is primarily served by collecting firewood.

Table 4: Censored Household Firewood Panel Regression Results

	Non-IV Estimates					IV Estimates				
		Elasticity at					Elasticity at			
	Derivative	P30	Median	P75	B*STD	Derivative	P30	Median	P75	B*STD
Consumption (+) (totcons)	**48.78***** (3.18)	**1.09**	**0.24**	**0.19**	**1.40, 1.03** (0.86), (0.61)	**137.20***** (4.71)	**3.47**	**0.66**	**0.36**	**3.93, 0.97** (1.64), (1.35)
Poverty (apghc1)	**1.17** (1.14)	**0.00**	**0.00**	**0.03**	**0.23** (0.40)	**0.72** (0.67)	**0.00**	**0.00**	**0.02**	**0.14** (0.42)
Wage Lab-Agri (fwag_h)	**0.64** (0.94)	**0.00**	**0.00**	**0.01**	**0.13** (0.28)	**0.05** (0.03)	**0.00**	**0.00**	**0.00**	**0.01** (0.58)
Wage Lab-Nonagri (fwnag_h)	**-1.75**** (2.26)	**0.00**	**0.00**	**-0.03**	**-0.32** (0.28)	**0.75** (0.14)	**0.00**	**0.00**	**0.01**	**0.14** (1.85)
Self-Empl-Nonagri (fnag_h)	**-3.29** (2.24)	**0.00**	**0.00**	**0.00**	**-0.54** (0.47)	**-2.90**** (2.43)	**0.00**	**0.00**	**0.00**	**-0.47** (0.38)
Cows owned (n_cow)	**0.17***** (3.41)	**0.35**	**0.09**	**0.09**	**0.54** (0.31)	**0.16** (0.67)	**0.32**	**0.08**	**0.08**	**0.51** (1.48)
Household size (+) (n_fam2)	**0.51***** (3.75)	**1.89**	**0.35**	**0.23**	**1.02, 0.75** (0.53), (0.42)	**-0.39** (1.21)	**-0.68**	**-0.27**	**-0.36**	**-.79, -1.69** (1.27), (1.93)
Education of head (+) (edu_head)	**0.14** (1.26)	**0.00**	**0.00**	**0.00**	**0.46, -0.05** (0.71), (0.33)	**-1.54** (1.02)	**0.00**	**0.00**	**0.34**	**-5.14, 4.79** (9.85),(17.5)
Female head dummy (d_hwom)	**-0.46** (1.35)	**0.00**	**0.00**	**0.00**	**-0.15** (0.22)	**-0.91** (1.54)	**0.00**	**0.00**	**0.00**	**-0.30** (0.38)
Fraction children (fra_chi)	**-1.51** (0.60)	**-0.22**	**-0.06**	**-0.06**	**-0.30** (0.98)	**1.98** (0.96)	**0.28**	**0.08**	**0.08**	**0.39** (0.80)
Fraction young male (fra_male)	**-0.85** (0.36)	**-0.21**	**-0.05**	**-0.04**	**-0.15** (0.81)	**2.01** (1.23)	**0.50**	**0.11**	**-0.21**	**0.35** (0.57)
Fraction young female (fra_ywom)	**-0.31** (0.14)	**-0.08**	**-0.02**	**-0.01**	**-0.05** (0.69)	**3.14*** (1.91)	**0.78**	**0.17**	**-0.46**	**0.51** (0.52)
Fraction old male (fra_oman)	**-1.86** (0.78)	**0.00**	**0.00**	**0.00**	**-0.14** (0.34)	**-0.12** (0.22)	**0.00**	**0.00**	**0.00**	**-0.01** (0.07)

Mid-caste dummy (mid_eth)	**0.18** (0.41)	**0.00**	**0.00**	**0.02**	**0.08** (0.40)	**0.30** (0.59)	**0.00**	**0.00**	**0.00**	**0.14** (0.46)
Low-caste dummy (low_eth)	**0.08** (0.18)	**0.00**	**0.00**	**0.00**	**0.02** (0.25)	**0.90** (1.20)	**0.00**	**0.00**	**0.00**	**0.27** (0.44)
Other Ethn. Dummy (oth_eth)	**-0.20** (0.32)	**0.00**	**0.00**	**0.00**	**-0.07** (0.45)	**0.69** (0.92)	**0.00**	**0.00**	**0.00**	**0.25** (0.54)
Buddhist Dummy (bud)	**0.69** (0.92)	**0.00**	**0.00**	**0.00**	**0.17** (0.37)	**0.96** (1.29)	**0.00**	**0.00**	**0.00**	**0.24** (0.36)
Muslim Dummy (muslim)	**1.06** (0.80)	**0.00**	**0.00**	**0.00**	**0.15** (0.37)	**0.52** (0.30)	**0.00**	**0.00**	**0.00**	**0.08** (0.50)
Other Relig. Dummy (rel_oth)	**0.65** (0.20)	**0.00**	**0.00**	**0.00**	**0.07** (0.68)	**4.35** (1.26)	**0.00**	**0.00**	**0.00**	**0.46** (0.72)
Firewood Collection Time (+) (et_cfire)	**0.06** (0.72)	**-0.02**	**0.05**	**0.09**	**0.17, 0.44** (0.46), (0.44)	**0.12** (1.25)	**0.35**	**0.10**	**0.09**	**0.35, 0.36** (0.54), (0.45)
n		2064					1946			
Chi-Sq Test for Joint significance P-value		0.00%					0.00%			

(+): Squared Term also included in regression. B*STD is calculated twice: first using derivative at median, then at median plus one standard deviation.
Absolute t-values in parentheses (for derivatives), half of prediction confidence interval width in parentheses (for B*STD).
*** denotes significant at 1%, ** at 5%, and * at 10%

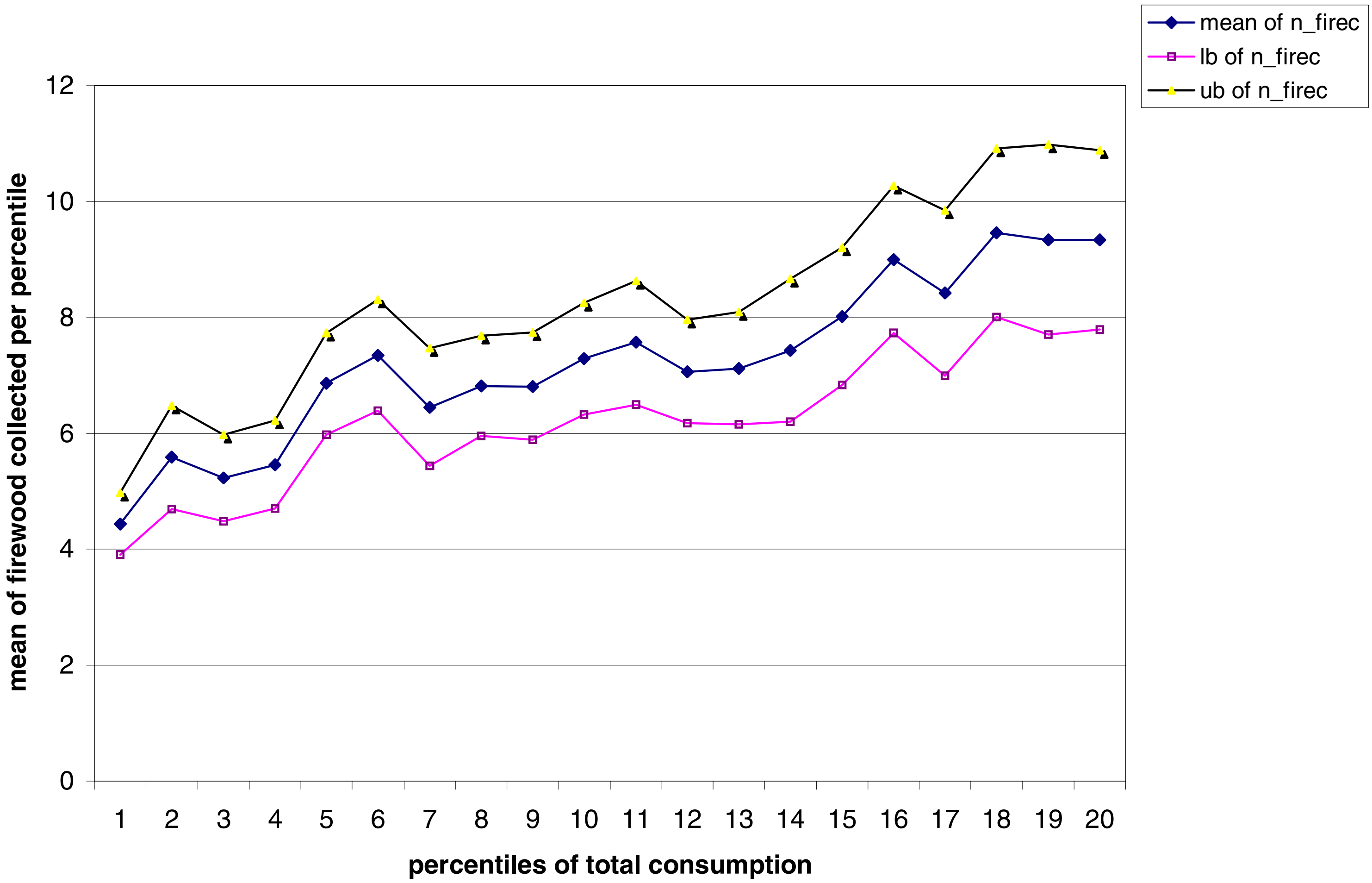

Figure 1: Mean firewood collected and 95% confidence limits for different percentiles of distribution of total household consumption in the regression sample

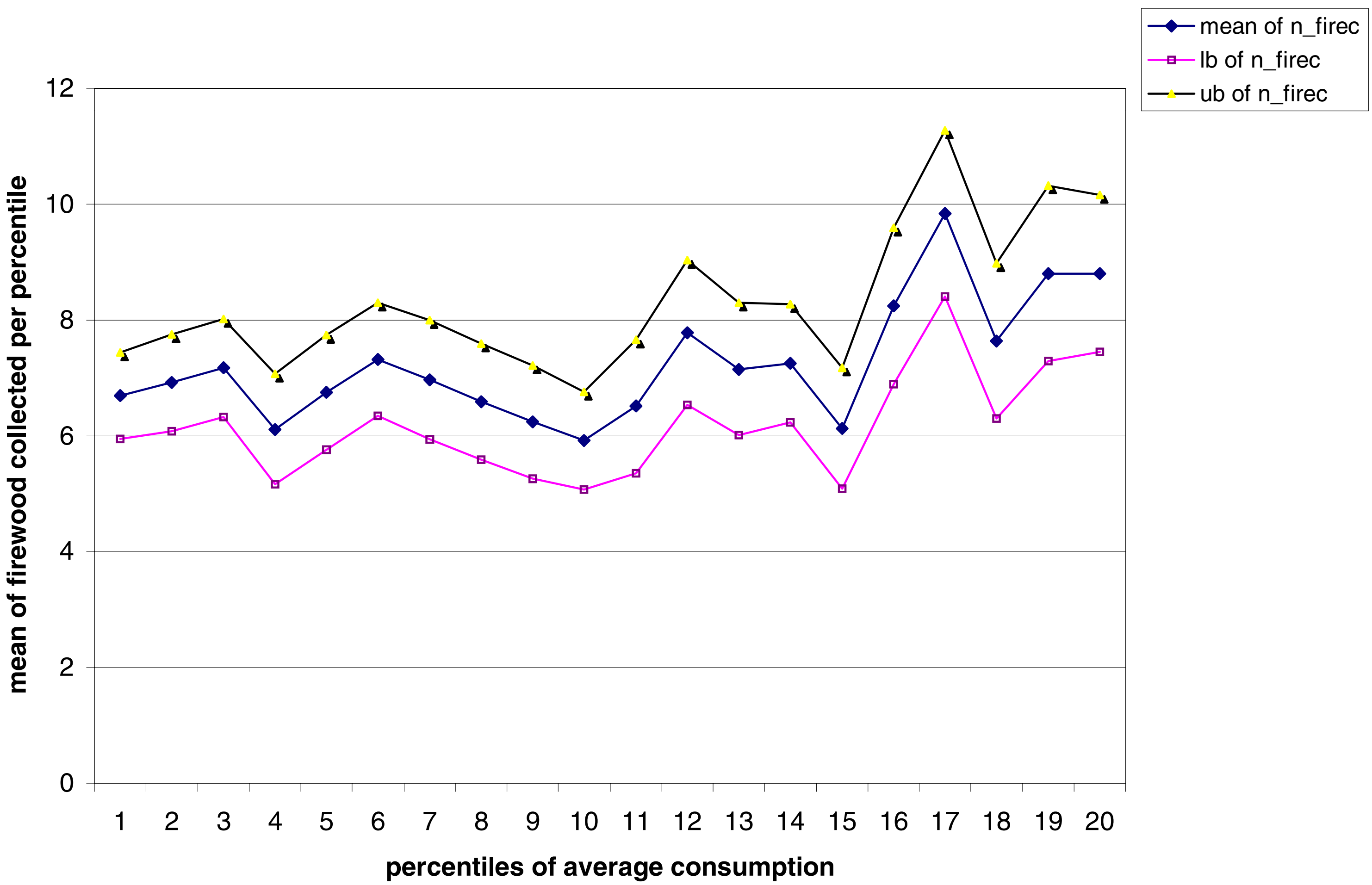

Figure 2: Mean firewood collected and 95% confidence limits for different percentiles of distribution of average (per capita) consumption in the regression sample

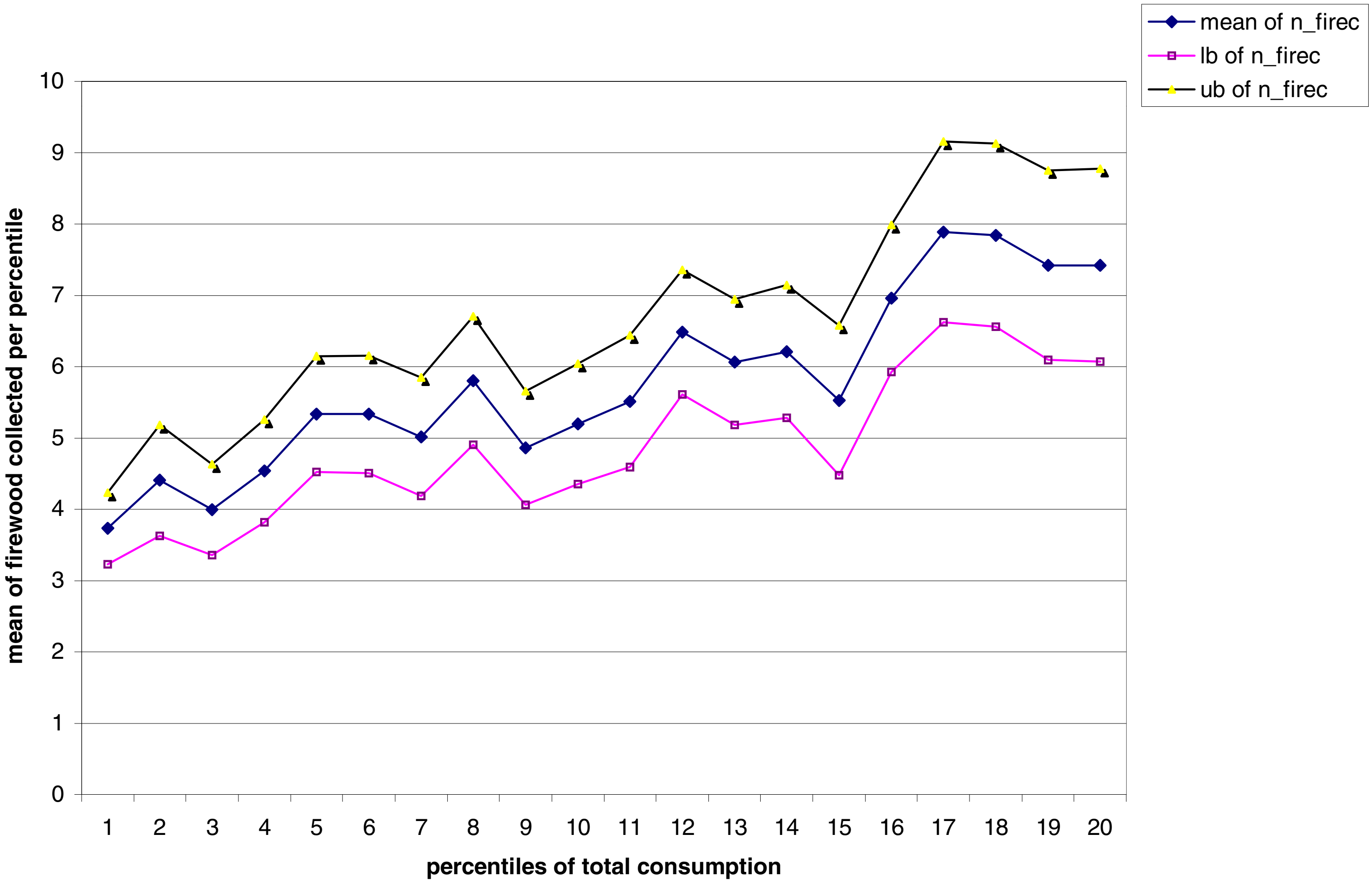

Figure 3: Mean firewood collected and 95% confidence limits for different percentiles of distribution of total consumption in the full sample

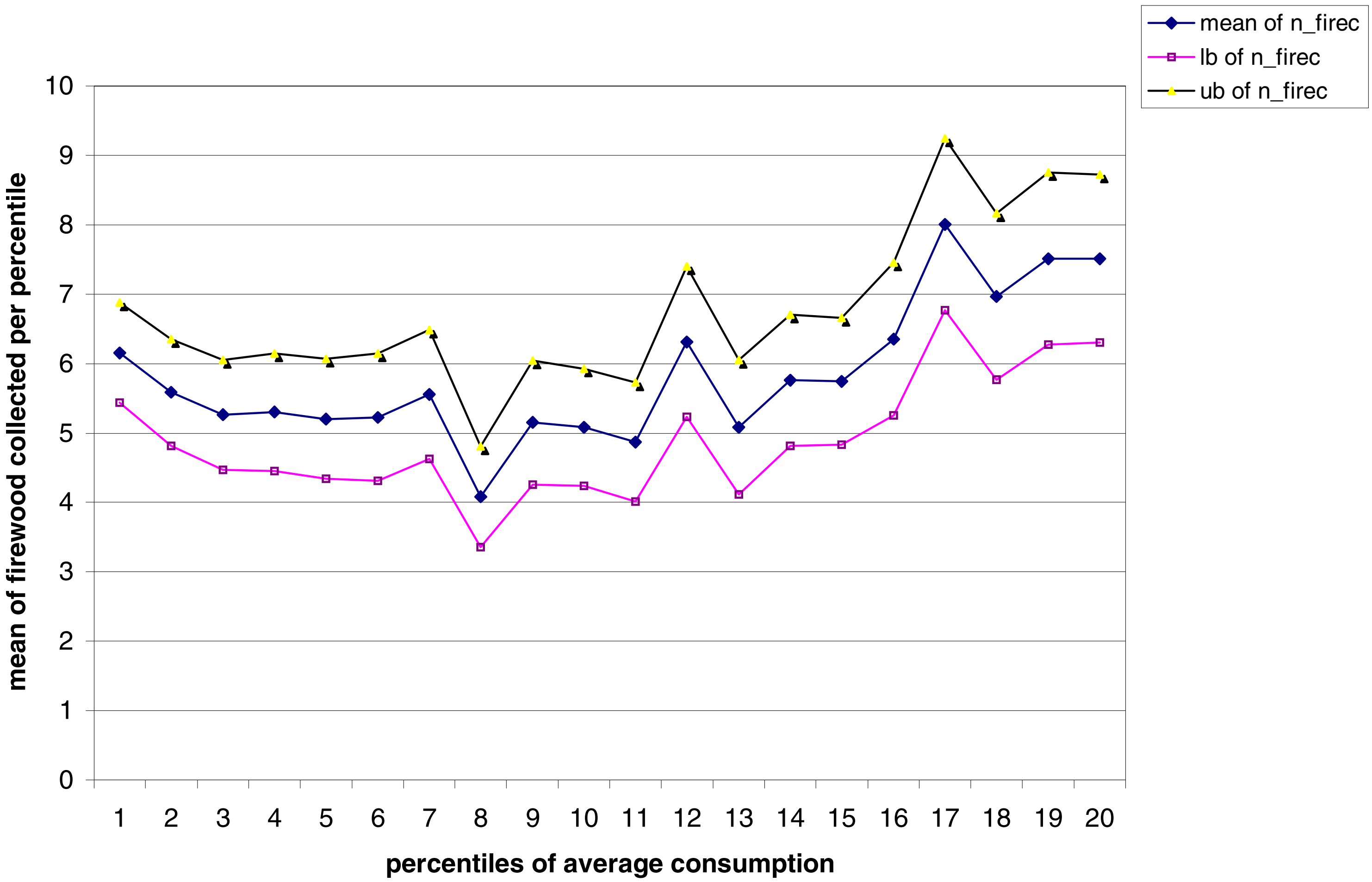

Figure 4: Mean firewood collected and 95% confidence limits for different percentiles of distribution of average (per capita) consumption in the full sample

Estimated Village Effects

We turn now to the estimated village effects in the determination of the latent variable F_{iv}^*. The baseline results are displayed in Table 5, while those corresponding to different versions of this regression (with different sets of explanatory variables) are shown in Table 6. Higher order terms involving squares are included for mean consumption, population size and elevation; for other variables was not included owing to lack of significance. Similar to Table 4, column of Table 5 present derivatives of mean village collection with respect to the corresponding variable, incorporating the effect of higher order terms included in the equation. The remaining columns present elasticities at the 30th, 50th and 75th percentiles and the effect of a unit deviation increase on the latent variable F_{iv}^* (or collections when collections are positive). Table 7 subsequently presents corresponding predictions that incorporate nonlinearities resulting from censoring.

The following variables are treated as endogenous in the regression, and are accordingly instrumented: village mean consumption, Gini consumption, poverty, population, household size, existence of forest user groups, mean and standard deviation of collection time, education of head, fraction of labor in nonagricultural occupations, cows per household, agricultural productivity, and time to Krishi center. The set of instruments includes rainfall, latitude, longitude, access to canals, electricity, post offices, banks, bus stops, police stations, health clinics, roads and markets, and population of nearest town.

The first point to note about the results in Table 5 is the strong positive effect of mean consumption, which is statistically and quantitatively the dominant influence on F_{iv}^*. One standard deviation change in mean village consumption raises F_{iv}^* by three to four bharis, over half the mean collection for the entire sample. The effect of poverty while positive is statistically and quantitatively insignificant. Since the relationship between consumption and collection at the household level was nonlinear, aggregation upto the village level may conceivably yield an effect of consumption inequality on collections. This effect also turns out to be insignificant. Taken together with the household regression estimates, this provides strong evidence at the village level against the poverty-environment hypothesis. Even the effect of land inequality (Gini land), which is separately included in the regression as a potential determinant of collective action, is quantitatively insignificant. These results therefore provide almost no basis for the view that deforestation in Nepal's *terai* can be blamed on high inequality or poverty.

Population size exerts a strong impact on collections, the relationship being inverse U-shaped (the first order term has a significant positive coefficient, while the square of population has a significant negative coefficient) as seen from the pattern of elasticities and the effect of one standard deviation increase in population. At the median level of population, its effect is positive but once it rises by one standard deviation from the median its effect becomes negative. This suggests that collections are initially rising with population, and then falling: Figure 7 below confirms this. A possible explanation for the inverse U-pattern is the argument advanced by Agrawal and Goyal (1997): with a small population, villages are close knit, and informal collective action within villages is fairly effective in regulating firewood collection. With rising population this effectiveness declines over some initial range, causing forest degradation and consequent efforts by residents to create quasi-formal regulatory institutions that hire forest guards and create sanctioning mechanisms. The fixed costs associated with creating such institutions justify their creation only in villages of a certain minimum size. The positive derivative presented in Table 5 thus needs to be interpreted with caution: it represents the effect of small (local) changes in population at the median population size on collections when collections are positive. The global effect of a unit standard deviation increase in population size could be significantly different from that predicted by multiplying this derivative with the standard deviation of population. Moreover, the effect on total village collections must incorporate changes in the number of households as well as changes in per household collections. We return to these issues below.

The formation of forest user groups has a statistically significant (at 10%) negative effect on collections, but the size of the effect is small.[22] Moreover, Table 6 indicates this effect continues to be negative but half the time it is insignificant

[22] The estimated coefficient is 0.52, slightly less than 10% of mean collections. So our estimate is not much different from that of Edmonds (2000a) for the Arun Valley. Our data set covers the entire country, and the evidence reported in Edmonds (2000b) suggests that forest user groups in the Arun Valley were more effectively implemented than elsewhere in the country. However, our estimate is less robust than Edmonds' for the Arun Valley, in the sense that it

when more explanatory variables are added to the regression, or turns positive when the formation of forest user groups is treated as exogenous.[23] This implies that the leading alternative to the poverty environment hypothesis, stressing community control based on existence of formal property rights and forest management by local communities, also fails to receive strong support --- especially when compared with the role of other factors.

The next set of variables represent a variety of potential determinants of informal collective action within the community. Two measures of heterogeneity --- caste and locational --- have quantitatively significant positive effects. More heterogenous villages presumably find it more difficult to agree on how to regulate access, or sanction members detected breaching regulations. Land inequality has a negative (but statistically insignificant) effect, consistent with an Olsonian theory in which higher inequality improves collective action owing to the concentration of power of a few dominant parties with encompassing interests. However ethnic fragmentation is positively and significantly related to collections whereas religious fragmentation does not have a significant effect; the latter is not surprising in these Nepalese villages where the vast majority (85% on average) is Hindu.

Mean collection time has a significant negative effect on collections at the village level. The contrast in the strength of this response with that identified in the household regression is surprising, where we found remarkably little intravillage responsiveness. It may indicate the importance of strong norms at the village level governing collection activities, which permit relatively little variability within the village, but large variations across villages. This suggests that deforestation would tend to be stabilized by the consequent decline in collection levels at the village level.

Occupational variables also have strong effects at the inter-village level: increased education, prevalence of nonagricultural occupations, and decline in livestock reduce collections significantly. For instance, a simultaneous one standard deviation increase in each of these three factors would reduce F_{iv}^* by over three and a half bharis, an effect which would balance neutralize the effect of a one standard deviation increase in mean consumption. This suggests that growth in living standards need not lead to a net increase in collections, as long as it is accompanied by corresponding shifts in occupational patterns and education. We return to this issue below in the discussion of Table 7.

However, the effect of modernization is quite complex, which may be accompanied by changes in productivity and transport. A rise in agricultural productivity is associated with a significant rise in F_{iv}^*: a one standard deviation change in land prices raises it by between a third and fourth of the mean collection level. This conforms to the frequently expressed notion that rising agricultural productivity reduces dependence on forests as a source of livelihood, thus reducing collective pressure within communities to conserve local forests.[24] Reduction in remoteness of villages owing to improvements in transport and road building gives rise to conflicting effects. Reduced time to dirt roads and markets is associated with a significant rise in F_{iv}^*, but reduced time to paved roads has the opposite effect. Remoteness thus has no simple relationship with collection incentives, incorporating changes in accessibility to market opportunities for sale of timber, as well as of various substitutes and complements for firewood. Given the absence of suitable data on prices of related products, or of models relating remoteness to patterns of prices and accessibility, it is difficult to identify the precise channels through which these effects operate.

We also find that collections rise with elevation and this is true while holding constant the effects of remoteness such distance from markets. This largely captures increase in heating requirement with an increase in elevation. Finally, we find that collections are somewhat lower in disaster prone areas.

Table 6 presents results for alternative specifications of the village regression, which add ethnic and demographic composition variables to the right hand side. The effects of these variables at the household level were found to be weak, which motivated their exclusion from the baseline specification. However these variables may conceivably exert

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does not survive when we treat the formation of forest user groups as exogenous, or introduce auxiliary explanatory variables to the regression (see Table 6).

[23] If the formation of user groups responds to decline in forest stock that have been partially caused by high levels of firewood collections, the sign of the endogeneity bias we find is exactly what one would expect *a priori.*

[24] Such effects would arise also with a rise in non-agricultural occupations within the village. However a shift to nonagricultural occupations raise the shadow cost of collection time more than does a rise in agricultural productivity, since nonagricultural occupations typically involve committing labor hours to an employer or a market location, which is difficult to combine with firewood collection. Whereas farming can be more easily combined with livestock grazing, and is thus more complementary with firewood collection.

indirect (general equilibrium) effects at the village level, either by influencing the existence or effectiveness of collective action, or the structure of prices and wages within the village. The first two sets of columns present the effects of adding these variables. Family composition variables exert surprisingly large effects, considering that these do not vary all that much across villages and exert weak effects at the household level. Moreover the pattern of collections varies with age and sex in a way contrary to the effects at the household level: collections are most sensitive to the proportion of village population accounted by old men (above the age of 65), followed by children (ages upto 15), then by adult males (between 15 and 65), followed by adult females (between 15 and 65), and finally by old women. Since young women tend to be most involved within the household for collecting firewood, and old men the least involved, this pattern is surprising, and must operate through general equilibrium effects that remain to be explained.

It is similarly difficult to explain why a greater proportion of low caste households tends to significantly lower collections at the village level. The last two sets of results in Table 6 introduce a food price and housing price index, the only price variables in the sample available for the majority of the sample. These price indices were calculated for five different regions of Nepal, so they capture other regional effects as well (it was for this reason that the baseline specification used regional dummies instead) as the price effects. Accordingly the region dummies are dropped when the price indices are included. The food price index turns out significant in only one regression, while the housing price index is insignificant throughout. Moreover the coefficient of the food price is positive when it is significant, opposite to the negative substitution effects that one would expect *a priori*.[25]

Nevertheless, it is comforting to note that our principal results from Table 5 continue to survive in a robust manner through all the specifications in Table 6: the strong positive effect of mean consumption, the irrelevance of poverty or economic inequality, the weak effects of forest user groups, the strong positive effects of ethnic fragmentation and locational heterogeneity, the strong negative effect of mean collection time, and the significant effects of occupational structure, education, agricultural productivity and remoteness.

One qualification needs to be stated: the reported standard errors does not take into account that some regressors were generated, and thus tend to underestimate the true standard errors. Bootstrapping is necessary to calculate the standard errors more accurately, and will be reported in future versions of the paper. If at all, such corrections will reduce even further the significance of poverty, inequality and forest user group variables, and reinforce our negative conclusions. Which of the significant variables will continue to remain statistically significant, however, remains to be seen. Variables that are significant at 5 % will continue to remain so at 10 % even if the standard error increases by 20 %. Moreover, the mean effect of one standard deviation change in each of the explanatory variables will remain unaffected; hence our remarks concerning relative *quantitative* significance will continue to be valid.

[25] Of course there will be related income effects if the farmers in the village are net sellers of food, which would tend to create a positive effect. But these income effects are likely to be mostly incorporated in the coefficient of the consumption variable.

Table 5 Village Regression Results, Baseline Specification

	Derivative[26]	Elasticity at			Derivative* One Standard Deviation Change [27]
		P30	Median	P75	
Consumption(+) (Mtotcons)	**210.10***** (5.24)	**5.20**	**1.50**	**1.16**	**3.00, 3.90** (1.12), (1.37)
Gini Consumption (ginicons)	**1.44** (0.38)	**0.37**	**0.09**	**0.05**	**0.14** (0.71)
Poverty (apgc1)	**1.10** (0.45)	**0.04**	**0.02**	**0.02**	**0.13** (0.55)
Population (+) (popward)	**2.24***** (3.93)	**1.64**	**0.27**	**-0.01**	**2.04, -5.80** (1.02), (2.00)
Household Size (m_nfam2)	**-0.07** (0.15)	**-0.29**	**-0.06**	**-0.04**	**-0.05** (0.71)
Forest User Groups (dfug3)	**-0.52*** (1.66)	**--**	**--**	**--**	**-0.26** (0.31)
Gini Land (ginicul)	**-2.12** (1.62)	**-1.25**	**-0.28**	**-0.16**	**-0.30** (0.36)
Ethnic Fragmentation (fra_eth)	**4.95***** (5.46)	**0.98**	**0.40**	**0.27**	**1.13** (0.41)
Religious Fragmentation (fra_rel)	**0.47** (0.40)	**0.00**	**0.00**	**0.01**	**0.09** (0.44)
St. Deviation CollectionTime (setcfir)	**1.28***** (4.64)	**1.32**	**0.37**	**0.26**	**1.14** (0.48)
Mean Collection Time (m_etcfir)	**-0.77***** (4.33)	**-3.01**	**-0.77**	**-0.50**	**-1.73** (0.78)
Education of Head (meduhd)	**-1.13***** (6.07)	**-1.13**	**-0.38**	**-0.32**	**-1.62** (0.52)
Fraction Non-Agri Labor (m_fnag)	**-4.77***** (2.30)	**-0.05**	**-0.04**	**-0.05**	**-0.55** (0.47)
Cows per Household (av_cow)	**0.93***** (3.87)	**2.50**	**0.66**	**0.43**	**1.58** (0.80)
Agri Productivity (avfpr)	**6.89***** (5.10)	**0.46**	**0.13**	**0.13**	**1.57** (0.60)
Time to Krishi Center (t_krishi)	**0.35***** (3.86)	**0.40**	**0.13**	**0.12**	**1.44** (0.73)

[26] (+): Squared Term also included in regression. B*STD is calculated twice: first using derivative at median, then at median plus one standard deviation. Absolute t-values in parentheses (for derivatives).

[27] Width of 95% prediction confidence interval in parentheses: (x) signifies a confidence interval of Prediction plus/minus x.

Time to Dirt Road (t_dirt1)	**-0.14***** (5.03)	**-0.04**	**-0.04**	**-0.09**	**-1.78** (0.69)
Time to Paved Road (t_paved)	**0.05*** (1.71)	**0.09**	**0.03**	**0.06**	**0.76** (0.87)
Time to Market (t_market)	**-0.04** (0.71)	**-0.05**	**-0.02**	**-0.01**	**-0.24** (0.68)
Elevation (+) (elev)	**1.12***** (2.58)	**0.32**	**0.20**	**0.13**	**0.96, 0.69** (0.73), (0.41)
Disaster Prone (d_disas)	**-0.71**** (2.10)	**--**	**--**	**--**	**-0.36** (0.33)
Region 1	**1.24** (1.51)	**--**	**--**	**--**	**0.52** (0.67)
Region 2	**-0.92** (1.32)	**--**	**--**	**--**	**-0.42** (0.62)
Region 3	**-0.70** (1.50)	**--**	**--**	**--**	**-0.28** (0.37)
Region 4	**0.27** (0.57)	**--**	**--**	**--**	**0.09** (0.31)
No. of zeros in data			**360**		
Proportion of Correct Prediction of zeros			**0.47**		
Mean Abs. Error for zero values			**5.64**		
No. of Positive Values in Data			**1502**		
Proportion of Correct Prediction of Positive Values			**0.85**		
Mean Absolute Error for Positive Values			**5.22**		

Table 6 Village Regression Results (Other Specifications)

	With Region Dummies				With Price Indices			
	With Ethnicity		With Family Composition		With Ethnicity		With Family Composition	
	Deri-vative	**Derivative* One Standard Deviation Change**	**Derivative**	**Derivative* One Standard Deviation Change**	**Derivati ve**	**Derivative * One Standard Deviation Change**	**Derivative**	**Derivative * One Standard Deviation Change**
Consumption (+) (Mtotcons)	**126.89** (3.69)	**1.81, 1.37** (0.96), (1.29)	**204.43** (4.99)	**2.92, 2.65** (1.15), (1.40)	**201.05** (6.47)	**2.87, 3.61** (0.87), (1.09)	**218.55** (5.87)	**3.12, 3.30** (1.04),(1.26)
Gini Consumption (ginicons)	**-5.10** (1.46)	**-0.49** (0.65)	**-2.54** (0.70)	**-0.24** (0.68)	**5.95** (1.92)	**0.57** (0.58)	**3.41** (1.10)	**0.32** (0.58)
Poverty (apgc1)	**0.25** (0.11)	**0.03** (0.53)	**-4.16** (1.53)	**-0.47** (0.61)	**0.73** (0.32)	**0.08** (0.51)	**-2.21** (0.81)	**-0.25** (0.61)
Population (+) (popward)	**0.42** (0.73)	**0.39, -8.03** (1.03), (1.94)	**4.79** (6.28)	**4.36, -4.80** (1.36), (2.13)	**0.70** (1.19)	**0.64, -5.62** (1.05), (2.21)	**4.58** (6.13)	**4.17, -2.67** (1.33),(2.66)
Household Size (m_nfam2)	**-0.13** (0.24)	**-0.09** (0.73)	**-0.32** (0.58)	**-0.23** (0.76)	**0.43** (0.71)	**0.31** (0.84)	**0.45** (0.64)	**0.32** (0.98)
Forest User Groups (dfug3)	**-0.39** (1.26)	**-0.19** (0.30)	**-1.24** (3.53)	**-0.62** (0.34)	**-0.49** (1.56)	**-0.25** (0.31)	**-0.92** (2.63)	**-0.46** (0.34)
Gini Land (ginicul)	**-0.02** (0.02)	**-0.00** (0.33)	**0.57** (0.37)	**0.08** (0.42)	**-2.05** (1.83)	**-0.29** (0.31)	**-0.26** (0.18)	**-0.04** (0.40)

Ethnic Fragmentation (fra_eth)	**5.93** (5.48)	**1.36** (0.49)	**3.50** (3.85)	**0.80** (0.41)	**6.53** (5.13)	**1.49** (0.57)	**3.38** (3.71)	**0.77** (0.41)
Religious Fragmentation (fra_rel)	**1.07** (0.85)	**0.20** (0.47)	**1.22** (0.94)	**0.23** (0.49)	**0.08** (0.07)	**0.02** (0.46)	**-0.17** (0.15)	**-0.03** (0.41)
St. Deviation Collection Time (setcfir)	**0.47** (1.61)	**0.42** (0.51)	**1.71** (5.44)	**1.53** (0.55)	**0.43** (1.48)	**0.39** (0.51)	**1.26** (4.04)	**1.13** (0.55)
Mean Collection Time (m_etcfir)	**-0.27** (1.50)	**-0.60** (0.79)	**-0.89** (4.39)	**-2.00** (0.89)	**-0.65** (3.98)	**-1.46** (0.72)	**-0.88** (4.99)	**-1.99** (0.78)
Education of Head (meduhd)	**-0.49** (2.36)	**-0.71** (0.59)	**-0.65** (3.40)	**-0.93** (0.54)	**-0.87** (4.20)	**-1.24** (0.58)	**-0.81** (4.33)	**-1.16** (0.53)
Fraction Non-Agri Labor (m_fnag)	**-0.58** (0.23)	**-0.07** (0.59)	**-4.88** (1.82)	**-0.56** (0.60)	**-3.74** (1.20)	**-0.43** (0.70)	**-4.79** (2.27)	**-0.05** (0.48)
Cows per Household (av_cow)	**0.77** (3.10)	**1.32** (0.83)	**0.76** (2.94)	**1.30** (0.87)	**0.70** (3.63)	**1.19** (0.64)	**0.71** (3.57)	**1.20** (0.66)
Agri Productivity (avfpr)	**6.37** (4.54)	**1.45** (0.63)	**2.43** (1.72)	**0.55** (0.63)	**7.17** (5.14)	**1.63** (0.62)	**2.25** (1.56)	**0.51** (0.64)
Time to Krishi Center (t_krishi)	**0.05** (0.52)	**0.20** (0.73)	**0.56** (5.89)	**2.35** (0.78)	**0.37** (3.77)	**1.53** (0.79)	**0.50** (4.87)	**2.07** (0.83)
Time to Dirt Road (t_dirt1)	**-0.08** (2.76)	**-0.94** (0.67)	**-0.05** (1.78)	**-0.67** (0.74)	**-0.15** (6.01)	**-1.81** (0.59)	**-0.09** (3.27)	**-1.09** (0.66)

Time to Paved Road (t_paved)	**0.00** (0.11)	**0.05** (0.85)	**0.03** (0.80)	**0.37** (0.90)	**0.10** (3.98)	**1.47** (0.72)	**0.08** (3.05)	**1.12** (0.72)
Time to Market (t_market)	**0.08** (1.51)	**0.52** (0.68)	**-0.07** (1.30)	**-0.45** (0.68)	**-0.08** (1.33)	**-0.46** (0.68)	**-0.08** (1.28)	**-0.46** (0.71)
Elevation (+) (elev)	**0.32** (0.78)	**0.27, 0.23** (0.69), (0.40)	**1.31** (2.88)	**1.13, 0.84** (0.77), (0.43)	**0.55** (1.05)	**0.47, 0.25** (0.88), (0.47)	**0.39** (0.83)	**0.34, 0.27** (0.80),(0.43)
Disaster Prone (d_disas)	**0.11** (0.32)	**0.06** (0.34)	**-1.23** (3.09)	**-0.62** (0.39)	**0.11** (0.33)	**0.06** (0.33)	**-0.71** (1.87)	**-0.35** (0.37)
Food price index (fpindex)	**--**	**--**	**--**	**--**	**-3.27** (0.59)	**-0.37** (1.24)	**11.32** (2.06)	**1.29** (1.23)
Housing price index (hpindex)	**--**	**--**	**--**	**--**	**4.34** (1.72)	**0.54** (0.61)	**-2.89** (1.22)	**-0.36** (0.58)
Region1	**1.48** (1.58)	**0.62** (0.77)	**0.41** (0.47)	**0.17** (0.72)	**--**	**--**	**--**	**--**
Region2	**-1.79** (2.20)	**-0.82** (0.73)	**-2.13** (2.78)	**-0.97** (0.69)	**--**	**--**	**--**	**--**
Region3	**-2.27** (3.79)	**-0.91** (0.47)	**-1.12** (2.09)	**-0.45** (0.42)	**--**	**--**	**--**	**--**
Region4	**-0.64** (1.22)	**-0.22** (0.35)	**0.10** (0.18)	**0.03** (0.36)	**--**	**--**	**--**	**--**

Ethnicity: fr_mideth	**2.15** (3.29)	**0.68** (0.41)	--	--	**2.20** (4.16)	**0.70** (0.33)	--	--
fr_loweth	**-2.51** (1.93)	**-0.37** (0.37)	--	--	**-2.32** (1.67)	**-0.34** (0.40)	--	--
Fr_otheth	**-11.51** (4.79)	**-3.37** (1.38)	--	--	**-10.13** (3.44)	**-3.07** (1.75)	--	--
Fr_bud	**2.58** (2.27)	**0.45** (0.39)	--	--	**-0.05** (0.05)	**-0.01** (0.37)	--	--
Fr_musl	**9.61** (3.21)	**1.06** (0.65)	--	--	**6.43** (1.99)	**0.71** (0.70)	--	--
Family composition: Child Labor (fr_chi)	--	--	**51.28** (4.83)	**3.38** (1.37)	--	--	**49.30** (4.52)	**3.25** (1.41)
Fr_male	--	--	**39.10** (3.85)	**2.08** (1.06)	--	--	**42.75** (3.90)	**2.28** (1.14)
Fr_ywom	--	--	**33.66** (3.10)	**1.57** (0.99)	--	--	**38.01** (3.35)	**1.77** (1.04)
Fr_oman	--	--	**70.98** (5.72)	**1.38** (0.47)	--	--	**65.74** (5.62)	**1.28** (0.45)
No. of zeros in data	**360**		**360**		**360**		**360**	
Proportion of Correct Prediction of zeros	**0.39**		**0.28**		**0.34**		**0.53**	

Mean Abs. Error for zero values	**4.83**		**4.87**		**6.90**		**2.08**	
No. of Positive Values in Data	**1502**		**1502**		**1502**		**1502**	
Proportion of Correct Prediction of Positive Values	**0.92**		**0.93**		**0.93**		**0.85**	
Mean Absolute Error for Positive Values	**5.07**		**5.05**		**6.33**		**4.39**	

Predictions Combining Household and Village Estimates, and Incorporating Censoring Effects

Now we put together estimates of all the parameters in equation (7) mentioned in the household and village results to generate predictions concerning changes on firewood collection taking censoring and nonlinearities into account. Specifically, we aggregate the effect of household and village characteristics to predict the latent variable F_{iv}^* , and subsequently calculate predicted firewood collection $F_{iv} = Max(F_{iv}^*, 0)$ for each household i in the sample. This enables us to predict the incidence of zeroes in collections, i.e., switches away from firewood to alternative fuel sources. Figure 5 plots the resulting predicted (and actual) mean collections for households against their consumption percentiles in the sample (grouped into 5% bands). The pink curve *pnfirec* connecting the square dots represents predictions generated by all the variables included in the regression, the yellow curve *pnfirec5* connecting the triangles represents predictions generated by ignoring variables statistically insignificant at 5%, and the blue curve *pnfirec10* connecting the crosses represents predictions generated by ignoring variables statistically insignificant at 10%. Actual collections are depicted by the black curve *n_firec* connecting the diamonds. While *pnfirec* systematically overpredicts collections at all levels, the same is not true when statistically insignificant variables are dropped. At the 5% level the predictive accuracy is highest, and these predictions track collections at the top end of the distribution reasonably well, while underpredicting at the bottom end. All the predictions however track the overall slope of the relationship between collections and consumption percentile reasonably well, and appear not to miss any important nonlinearity in the data.

The predicted collections are subsequently aggregated across households within a village in order to generate predicted total (rather than per household) collection for each village, which is relevant for assessing the impact on deforestation. Table 7 reports effects of changing each significant right hand side variable by one standard deviation in the sample, keeping all the other variables (significant at either 5 % or 10 %) fixed at their median values. These predictions thus incorporate the effects of nonlinearities with respect to certain variables such as consumption and population sizes, the effects of censoring, and of changing number of households when we vary population. Besides the effects on total collections at the village level, it also reports effects on switching behavior, i.e., the number of households predicted to not collect firewood at all in each village. Even though the estimation used 1583 observations, the predictions could be evaluated for 1704 observations, as some variables turned out to be insignificant and we lost fewer observations due to missing values.

One standard deviation changes are considered for the continuously varying variables in the regression. Such changes do not make sense for discrete or dummy variables such as the existence of a forest user group or occurrence of a disaster in the last five years, the two significant dummy variables. Instead, the effects of one standard deviation changes in continuous variables are obtained for each of the four possible combinations of the dummy variables. For each combination, it is also obtained separately for variables that are significant at 5% and 10% respectively. Since forest user group is insignificant at 5% the effects at 5 % when such a group is present is the same as when it is not. Therefore at 5 % results are reported only when such a group is not present. Since the disaster variable is significant at 5% we ought to compare the predictions corresponding to disaster and no disaster in order to assess its effect.

In each cell three numbers have been entered. The first cell gives the total number of households out of 1704 predicted to not collect any firewood before the change. This number is obtained by calculating $F_{iv} = Max(0, F_{iv}^*)$, where F_{iv}^* is predicted for each observation using the observed values of the variable under consideration, while holding other significant variables at their median values, and counting the number of resulting zeros. The second number reports the change in the number of households not collecting when the variable corresponding to the row increases by one standard deviation. A positive number means that the number of households not collecting has increased and vice versa. The third number in the cell is the change in the total number of bharis collected by all the households in the village, obtained by summing F_{iv} over all households in the data, which mainly belong to the *terai* region.[28]

[28] Note that the reference point is the predicted F_{iv} before the variable under consideration changes from its observed values. This point changes with the variable under consideration. For instance, at the observed values of the land Gini, all households are predicted to be collecting firewood. This continues to be the case when the Gini increases by one standard deviation, while the total number of bharis collected goes down by 743. When there is no switching and the only change occurs in the amounts collected, the entries in all columns corresponding to the row for that variable will

First consider the effect of changes in mean village consumption. When we use only variables significant at 5% for prediction, we have 18 households not collecting in no-disaster areas and 24 not collecting in areas where disaster has occurred. After an increase in wealth leading to one standard deviation change in consumption, 3 fewer households are collecting positive firewood levels in the former case, and 7 fewer households in the latter case. In other words, wealth increases cause a few more households to switch to collecting firewood. However, the effect of collection levels of those who collect before and after is large. The corresponding effect on total collections is enormous, approximately 14 thousand bharis, i.e., whereas collection levels averaged 10 thousand bharis before the change, so total collections more than double. The resulting collection patterns are plotted against consumption percentiles in Figure 6, both before and after the change (using variables significant at 5%). Predicted collections before the change are depicted by the yellow curve labeled *pnfirec5* (connecting the triangles) and those after the change are depicted by the pink curve *sd_pnfire5* (connecting the squares), while the actual observed collections are depicted by the black curve *n_firec* connecting the diamonds. [29] Collections are predicted to double (or more than double) uniformly throughout the consumption distribution, except at the very top.

Consider next the effect of a unit standard deviation increase in population size. The effect on total collection is negative, in contrast to the positive derivative at the median reported in Tables 5 and 6. The discrepancy is explained by the nonlinearity of collections at the household level with respect to village population. Recall from the discussion of Tables 5 and 6 that the square of *pop_ward* had a significant negative derivative, in contrast to the significant positive derivative of *pop_ward* itself, creating an inverse-U shape. It is interesting that this negative effect on per-household collection overwhelms the effect of an increase in the number of households to create a negative effect on total collections. Figure 7 illustrates the pattern of predicted per household collections against population percentiles before (pink curve *pnfirec5* joining the square plots) and after (yellow curve *sd_pnfire5* joining the triangle plots) the population increase, besides the pattern of observed collections (black curve *n_firec* joining the diamond plots). The inverse-U pattern with respect to village population is now clearly visible in *pnfirec5:* the top 5% of the most populated villages do not collect at all. The uniform increase in population size causes mean collections in the top 70% of the most populated villages to fall, and the bottom 30% to rise. Those between 90-95 percentiles also switch to alternate fuels entirely. These results thus suggest caution in linear extrapolations of the effect of small increases in population size, as they fail to incorporate moderating influences that come into play for larger increases. One possible interpretation of these results has already been discussed above: rising population levels and the accompanying effect on deforestation may be creating pressures for emergence of resource management institutions that succeed in moderating firewood collection thereafter. If such institutions entail expenditure of fixed costs, they are particularly viable in large villages.

Table 7 indicates that other significant variables (with the exception of land inequality) have modest effects on total collections (and little effect on switching), of the order of 2 to 3 thousand bharis, approximately a third to a fifth of status quo collections. Given absence of significant nonlinearities or censoring effects, the results suggested by Tables 5 and 6 emerge: modernization, fragmentation and remoteness have moderately significant effects.

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be the same. This is due to the fact that the only difference across the columns will be in the realization of the dummy variables, which will shift collections at all points by the same amount, leaving the differences unchanged.

[29] The predictions plotted here before the change differ from those plotted in Figure 5 because the former predictions allowed all right hand side variables to vary as observed in the sample, while Figure 6 and Figure 7 freeze variables other than consumption or population at their median values.

Table 7 Predicted Change in Censored Firewood Collection Due to one Standard Deviation Change*

	No Forest User Group				Forest User Group	
	No Disaster		Disaster		No Disaster	Disaster
	At 5 % level	**At 10% level**	**At 5 % level**	**At 10% level**	**At 10 % level**	**At 10% level**
Consumption (+) (mtotcons)	18, -3, 14468	14, 1, 14469	24, -7 14465	15, 0 14469	15, 0 14469	18, 15, 14468
Population (+) (popward)	94, 89, -2293	84, 66, -2377	109, 94, -2225	94, 69, -2329	94, 63, -2342	94, 89, -2291
Ethnic Fragmentation (fra_eth)	0, 0, 1929	0, 0, 1929	0, 0, 1929	0, 0, 1929	0, 0, 1929	0, 0, 1929
St. Deviation of Collection Time (setcfir)	0, 0, 1941	0, 0, 1941	0, 0, 1941	0, 0, 1941	0, 0, 1941	0, 0, 1941
Collection Time (m_etcfir)	0, 20, -2899	0, 0, -2906	0, 29, -2883	0, 10, -2906	0, 0, -2906	0, 20, -2898
Education of Head (meduhd)	0, 5, -2603	0, 0, -2604	0, 17, -2597	0, 0, -2604	0, 0, -2604	0, 5, -2603
Fraction Non-Agri Labor (frnag)	0, 0, -2134	0, 0, -2134	0, 1, -2134	0, 0, -2134	0, 0, -2134	0, 0, -2134
Cows per HH (av_cow)	0, 0, 2640	0, 0, 2640	0, 0, 2640	0, 0, 2640	0, 0, 2640	0, 0, 2640
Agri Productivity (avfpr)	0, 0, 2708	0, 0, 2708	0, 0, 2708	0, 0, 2708	0, 0, 2708	0, 0, 2708
Time to Krishi Center (t_krishi)	0, 0, 2508	0, 0, 2508	0, 0, 2508	0, 0, 2508	0, 0, 2508	0, 0, 2508
Time to Dirt Road (t_dirt1)	34, 34, -3019	22, 12, -3062	34, 73, -2980	34, 34, -3036	22, 46, -3045	34, 34, -3019
Time to Paved Road (t_paved)	--	0, 0, 1324	--	0, 0, 1324	0, 0, 1324	0, 0, 1324
Elevation (+) (elev)	0, 0, 2124	0, 0, 2124	0, 0, 2124	0, 0, 2124	0, 0, 2124	0, 0, 2124

* in each cell first number is predicted number of household not collecting firewood, second number is change in number of households not collecting firewood after increase of one standard deviation in the variable, third number is the change in total firewood collected after one standard deviation change in the variable.
** total number of households = 1704

Figure 5: Percentiles of Total Consumption Vs Actual and Predicted Firewood Collection

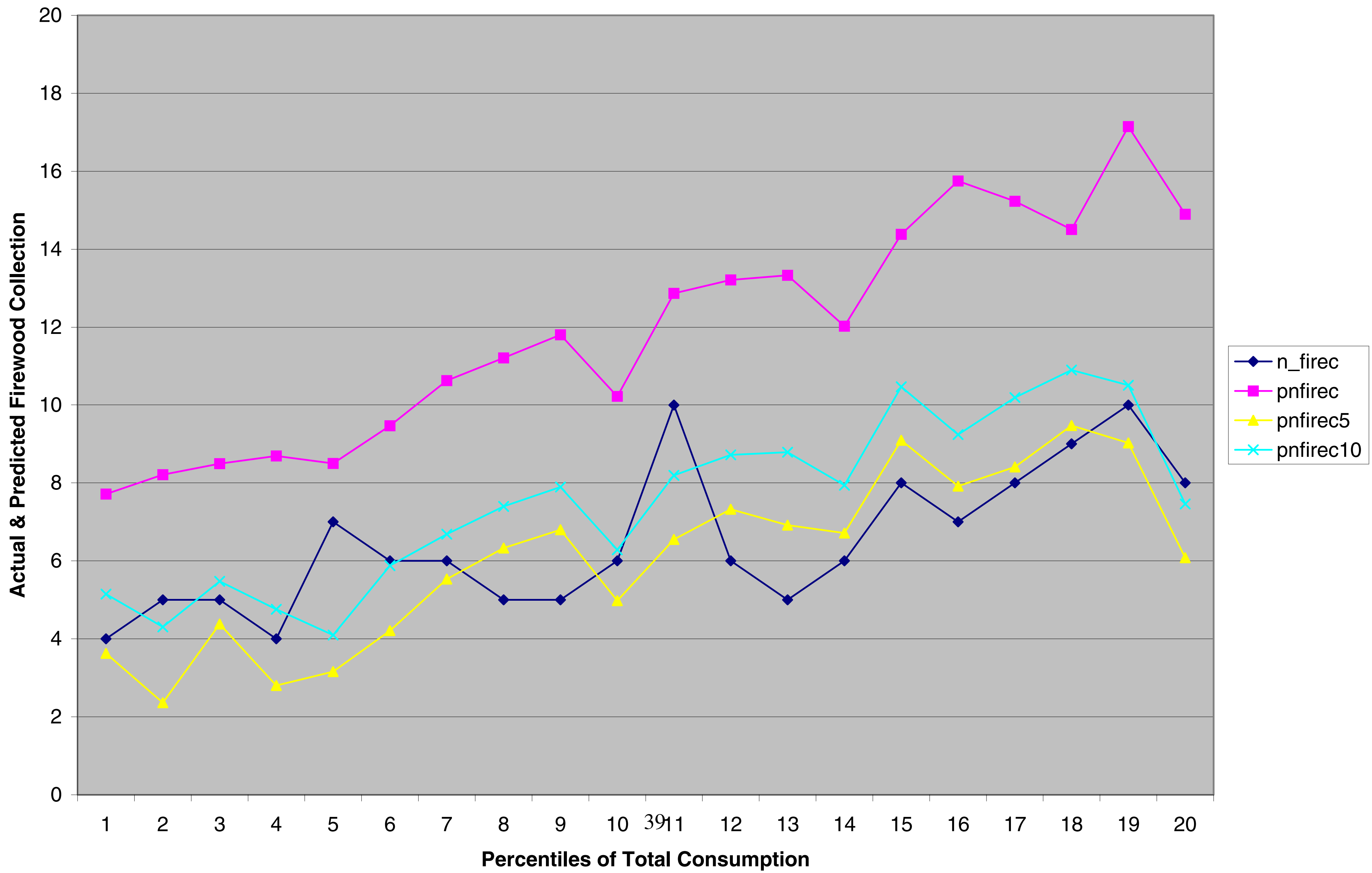


Figure 6: Percentiles of Consumption Vs Actual & Predicted Firewood Collection (before and after one Sd.Dev. change in consumption and with disaster)

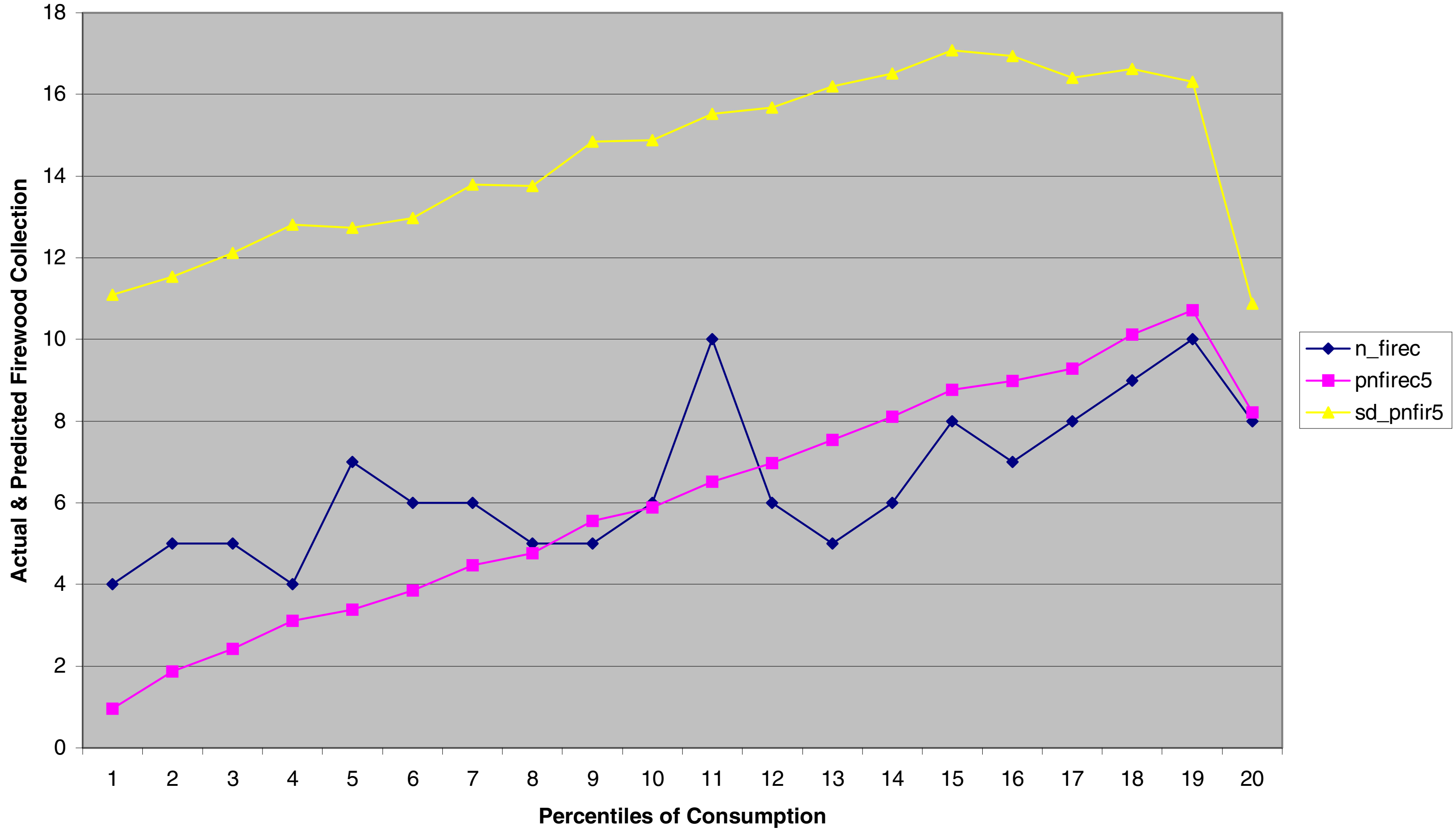
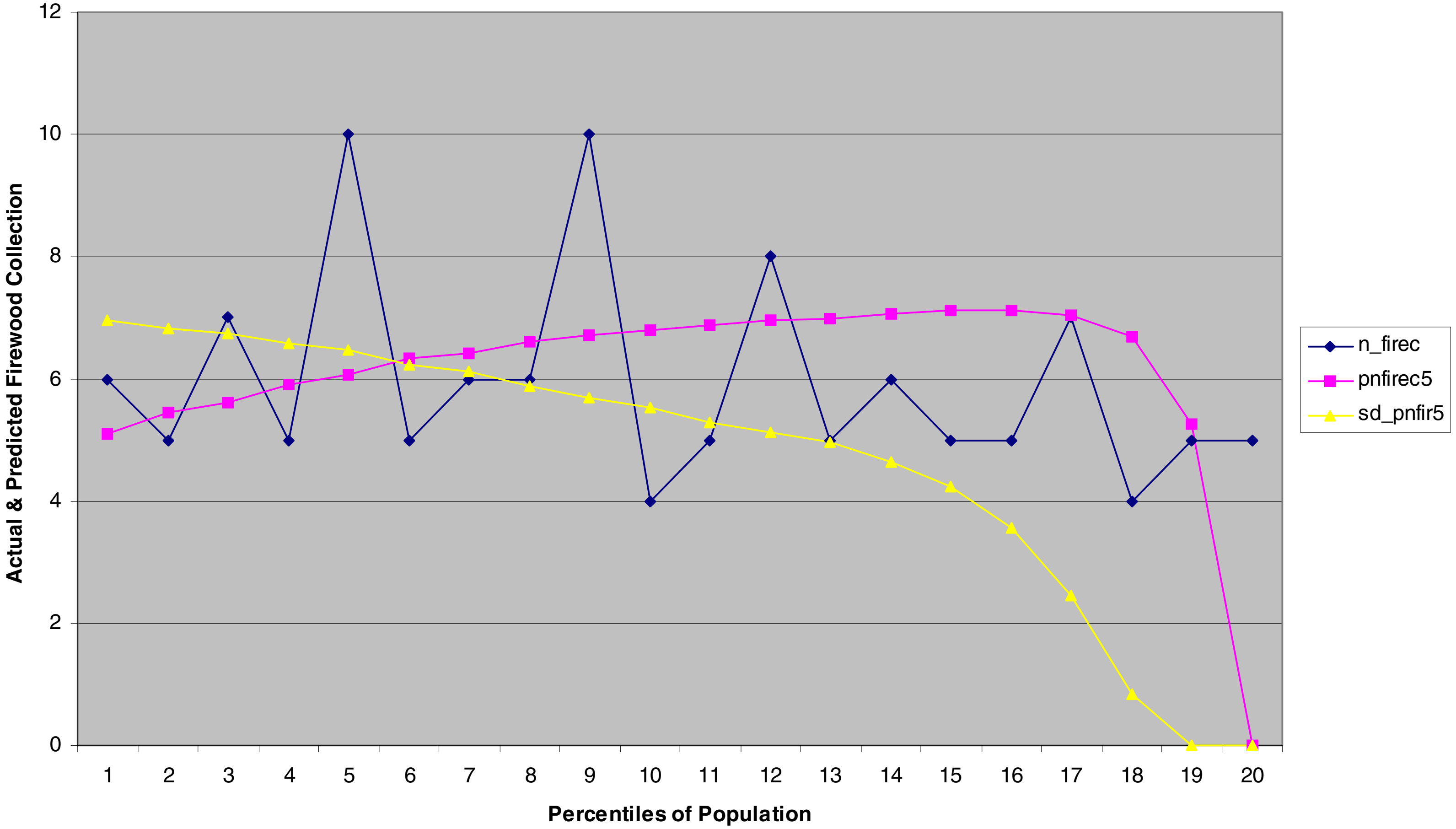


Figure 7: Percentiles of Population Vs Actual & Predicted Firewood Collection (before and after one Sd.Dev. change in population and no disaster)



7. CONCLUDING REMARKS

In summary, the two principal hypotheses in existing literature, based respectively on poverty and community control, receive little empirical support in the context of firewood collection in Nepal. More generally, there is little evidence that economic inequality has a significant effect on collection activities. Collective action has modest effects, and is in turn a function mainly of ethnic and locational heterogeneity. And even the effects of these variables are moderate compared with the effects of differences in living standards, patterns of education, occupation, agricultural productivity and market opportunities. In assessing the effect of population growth we found that the effect of small rises in population might be expected to be significantly positive, whereas large rises cause total collections at the level of the village to decline (presumably owing to endogenous institutional responses). `Modernization' , which typically involves some mixture of all of these changes, would therefore be associated with a rich and complex set of effects. In an effort to assess these, we intend to simulate the effects of exogenous changes in population growth rates, agricultural technology and market integration. This will require estimation of a richer structural model incorporating interactions across endogenous variables of the model, and will be reported in future versions of the paper. While these results are still preliminary, they do point to the need to shift attention away from the hypotheses that have received the greatest attention so far, towards understanding the modernization process better. While reducing poverty and inequality are laudable policy goals in their own right, one cannot make a case for distributional policies in Nepal purely on grounds of their effect on firewood collection incentives. Large increases in population sizes (of an order of one standard deviation) need not be a major concern either. More important from an environmental standpoint are policies that ensure that growth in living standards are accompanied by suitable spread of education, nonfarm opportunities and availability of fuelwood substitutes.

The effects of forest user groups is to reduce collections at the household level to a moderate degree, if at all. The estimates in certain versions are of an order of 5 to 10%, consistent at the higher end with those obtained for the Arun Valley by Edmonds (2000a). Our assertion of the weakness of their effect is *relative* to the effect of changes in living standards or modernization variables, variations in which appear to account for much larger order variations in collection levels across villages in our sample. Considering the complexity of the modernization process, even modest reductions in firewood collection may be welcome, particularly when confronted with the threat of a vanishing forest. So policies that create and nurture forest user groups should continue to be encouraged. Our main contention instead concerns the importance of community control mechanisms in explaining the large differences in observed firewood collection across different villages, *vis-à-vis* other potential explanations in terms of growth in living standards or patterns of modernization.

Our analysis suffers from a number of shortcomings, many of which stem from the nature of the dataset employed. The results are based on cross-sectional differences across households and village at a point of time, whose relevance to understanding shifts over time is difficult to assess. Panel data which provides data for particular households and villages over different points of time would be a big step forward, but we are not familiar with any such dataset concerning use of common property resources in any developing country context.

Other data limitations concern absence of information on forest stock and quality: do differences in firewood collection levels drive deforestation? Or are other factors, such as changes in forest area resulting from conversion to agricultural land, private concessions to timber merchants, or illegal felling more important? To assess this question we would need data concerning changes in forest stock over time. One possibility is to use estimates of forest area and density from remote sensing satellite images, as Foster, Rosenzweig and Behrman (1999) have done. It would also help to check the validity of our assumption that mean collection time within a village is a good proxy for the forest stock.

The Nepal LSMS data is also poor with respect to information concerning prices and availability of fuel substitutes and complements to firewood: the responses contain many missing values which shrink the sample size considerably and they were not included in the regressions to avoid possible sample selection biases. Understanding the process by which the extent of substitutability among alternative energy sources is expanded is of crucial policy importance. Presumably the process of modernization can be modified by policies of expanding transport networks, and increasing availability of fuel substitutes. Policies affecting educational spread and occupational structure (such as encouragement of tourism and horticulture) may also have benign environmental effects.

Little or no information was available concerning informal collective action governing use of forest products, which caused us to rely on some proxies for informal collective action in other spheres, and a set of potential determinants of collective action. This prevented us from directly checking the extent and determinants of collective action, and their effectiveness in limiting firewood collections. It would also help to know of methods of effective enforcement of use regulations by either formal or informal means. Future versions of this paper will report the effect of these determinants on other forms of collective action within the village, measured by existence of irrigation or credit groups.

In our ongoing extension of this project to villages in the Indian Himalayas, we are attempting to gather better information on all these dimensions. Contrasting the experience of different Indian states, and of these with Nepal will also be interesting. It is important to reiterate that the patterns observed in Nepal may not be representative of resource problems in other developing countries, and it is necessary to extend our analysis to the contexts of alternative resources and alternative countries before any general conclusions can be drawn.

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APPENDIX: DETAILS OF ESTIMATION PROCEDURE

First, we describe how Honore's (1992) estimator can be applied to our context to wash out village effects in the censored household regression. For two different households i and j in the same village v with errors e_{iv}^3 and e_{jv}^3, the village effect $\alpha_v \equiv r_1 + Z_v f_2 + u_v$ is the same. Under the assumption that e_{iv}^3 and e_{jv}^3 are i.i.d. conditional on $(X_{iv}, X_{jv}, \alpha_v)$, e_{iv}^3 and e_{jv}^3 have the same distribution for a given value of the vector $(X_{iv}, X_{jv}, \alpha_v)$. This in turn induces the equality in distribution of F_{iv}^* and F_{jv}^* and hence of F_{iv} and F_{jv}. As we change the value of $(X_{iv}, X_{jv}, \alpha_v)$ the distribution may change but whatever it is, it will be the same for F_{iv} and F_{jv}. This implies that the expected value of F_{iv} given that it lies in particular region, say A, such as greater than zero will equal the expected value of F_{jv} lying in the same region. Hence,

$$E(F_{iv} \in A) - E(F_{jv} \in A) = 0$$

Many such moment conditions can be created. Honore uses one that can be viewed as a first order condition to the following minimization problem in which α_v has been differenced out:

$$\text{Min} \ \Sigma_v \Sigma_{i,j} \chi(F_{iv}, F_{jv}, (X_{iv} - X_{jv})\, b),$$

where v denotes a village, i and j belong to the set of all pairs of observations for village v,

$$\chi(.) = \{\max(F_{iv}, \Delta X_v b) - \max(F_{jv}, -\Delta X_v b) - \Delta X_v b\}^2 + 2 \bullet 1\{ F_{iv} < \Delta X_v b\} (\Delta X_v b - F_{iv}) F_{jv} + 2 \bullet 1\{ F_{jv} < -\Delta X_v b\} (-\Delta X_v b - F_{jv}) F_{iv}$$

and

$$\Delta X_v = X_{iv} - X_{jv} .$$

This function is convex and twice differentiable in b except at a finite number of points. Even so, in the beginning we use a downhill simplex algorithm, which is a global minimization routine but is not locally very accurate. But this gets us to the neighborhood of the minimum. Once we get close to the global minimum, the Newton-Raphson procedure, which uses local curvature information, is used to get to the minimum precisely[30]. Honore proves the consistency and asymptotic normality of the estimator.

As explained in the text, we use instruments for endogenous household characteristics. This requires us to first predict the values of these on the basis of the instruments, and then use the predictions as proxies. Censoring problems arise in predicting some of these endogenous household variables, and not in others.

Total consumption (**tot_cons**), family size in adult equivalent units (**n_fam2**), average consumption per person per day (in 1985$) (**cons_dol**) are continuous uncensored endogenous variables. Accordingly these have been predicted by the fixed effect generalized method of moments (GMM) estimator[31]. Similar to the least squares method, the fixed effect GMM also uses deviation of the dependent and independent variables from village-specific means. The moment conditions used are the uncorrelatedness of the household error and the instruments. Under this assumption GMM is known to be the most efficient and is therefore used here. It is obtained by performing the following minimization on transformed data. Let **m** be the **K** dimensional vector of moment conditions for the uncorrelatedness of the error and the instruments , where K is the number of instruments and **V(m)** be the variance matrix of these moment conditions. Then GMM is obtained by minimizing the quadratic form $\mathbf{m'}\ \mathbf{V(m)}^{-1}\ \mathbf{m}$ (see Lee (1996), ch. 2).

In contrast to consumption, the number of cows owned per household (**n_cows**) and education of head (**edu_head**) measured by years of schooling are endogenous count variables; accordingly fixed effect Poisson regression is used for prediction of these variables (see Hausman, Hall and Griliches (1984)).

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[30] We are thankful to Bo Honore' for providing us the computer program for this part of estimation.

[31] Cons-dol is used to construct the average poverty gap Apghc1=max(0,(1-cons_dol)) .

The remaining endogenous household variables, occupational structure (**fwag_h, fnag_h, fwnag_h**), value of cultivated land (**v_c_land**), non farm business assets (**n_f_bus**) are censored variables and predicted using Honore's procedure. Once **b** is estimated it can be treated as known. Then (7) can be rewritten as

(8) $F_{iv} - X_{iv}\, b = \text{Max}(-X_{iv}\, b,\; r_1 + Z_v\, f_2 + u_v + e_{iv}^3 + e_{iv}^4)$,

where e_{iv}^4 is the error arising from errors in estimating r_2, r_3 etc at the first stage (which probabilistically vanish in large samples). For compactness, denote F_{iv}-$X_v b$ by y_{iv} and $-X_{iv}b$ by c_{iv}. Then the remaining parameters r_1 and f_2 in equation (7) are estimated using Powell's (1986) symmetrically trimmed least squares estimator (STLS) applied to equation (8). It assumes that the distribution of the error term ($u_v + e_{iv}^3 + e_{iv}^4$) conditional on Z_v is symmetric. The estimator is obtained by minimizing [32]

$1/T\, \Sigma_{i,} \{y_i - \max(0.5(y_{iv} + c_{iv}), r_1 + Z_v f_2)\}^2$, where T is the total number of observations.

Before STLS is applied to eq. (8), the village endogenous variables are predicted using instruments at the village level, as explained in the text.

[32] Maximum likelihood was also used for estimating (8) under the assumption of normal distribution but this resulted in poor predictions.