WHO COLLECT RESOURCES IN DEGRADED ENVIRONMENT? A CASE STUDY FROM JHABUA DISTRICT, INDIA

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Abstract

This paper examines the impact of the variation in stocks of three resources, namely, water, forests and fodder biomass, on resource collection time of rural households in India, especially women. Using household level data from 543 households across 60 villages in the Jhabua district of Madhya Pradesh, we estimate reduced form gender-specific time allocation equations derived from a household production model. An increase in groundwater scarcity makes women and children spend more time in water collection. An increase in the total biomass availability in the commons increases the time spent by men and women in grazing activity in addition to making men and women more likely to go for fuelwood collection. The results taken together indicate significant time impacts of natural resource scarcity. Our analysis has important implications for natural resource management initiatives such as community forestry and watershed development programmes, and these programmes have the potential to alleviate poverty by affecting the time allocation decisions of rural households, particularly women. This paper also tries to understand some of the trends emerging from the quantitative/econometric analysis using insights from social anthropology.

Key Words: Dependence on commons, Rural India, Time allocation decisions, Gender differences, Natural resource management initiatives, Anthropology.

Who Collect Resources In Degraded Evnironments ? : A Case Study From Jhabua District, India

Shreekant Gupta, Neetu Chopra, Supriya Singh,
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I. Introduction

The problem of natural resource degradation in poor countries such as India is increasing at an alarming pace. Poor people, who are directly dependent on their local environment for their livelihoods, are likely to feel the worst impact of natural resource scarcity. For example, if forest degradation forces households to spend more time in the pursuit of firewood—an essential commodity for the household—households are likely to have less time for income-generating activities (Kumar and Hotchkiss, 1998; Bluffstone, 1995; Cooke, 1998a, 1998b), with consequent welfare implications. Excess use of common forests for fuelwood increases resource collection times, thus decreasing the time individuals can devote to other productive activities which in turn impose welfare costs on them in terms of lower incomes (Köhlin and Amacher, 2004). Furthermore, since women tend to be the primary collectors of natural resources,[1] they in particular are likely to suffer the consequences of resource degradation. In some developing countries, women spend seven times as many hours collecting wood and water in comparison with men. A study by the World Health Organization estimates that the energy used to carry water consumes one-third of a woman's daily caloric intake (Centre for Science and Environment, 2004). If resource scarcity forces women to spend more and more time in resource collection, women are likely to have less time for income-generating activities. To the extent that increases in women's incomes are disproportionately invested in improved education, health, and nutrition, not only of themselves, but also their children, a decrease in women's income is likely, overtime to lead to further decreases in household incomes.

Although there is a lot of anecdotal evidence, the literature that tries to understand the impact on a household' s and women's time of a change in the availability of basic natural resources—forests, grazing lands, surface and groundwater sources— is limited which also controls for other factors that may affect this decision (Kumar and Hotchkiss, 1988; Cooke, 1998a; Ilahi and Grimard, 2000.[2]).

1 Also see Ilahi, 2000, for a survey

2 Amacher, Hyde and Joshee (1993) assert that women are primarily responsible for activities like fuelwood collection, water collection and accessing local services. Also, in a study based in rural Pakistan, Filmer and Pritchett (1996) show that 60% of time devoted to fuelwood collection comes from women and children while Loughran and Pritchett (1997), in a study in Nepal, find that 69% of water collectors and 61% of fuelwood collectors are women.

Kumar and Hotchkiss (1988) and Cooke (1998a) both use data from the Nepal Energy and Nutrition Survey (NENS 1982-83), a survey of 120 households from six villages in three hill districts of rural Nepal, to examine the impact of environmental degradation on the time households in general, and women in particular, spend on the collection of three environmental resources—fuelwood, cut grass, and fodder. Kumar and Hotchkiss measure deforestation via the time a household takes to collect 20 kg of fuelwood while Cooke captures scarcity through an increase in the shadow price of a resource.[3] This variable, in turn, is defined by Cooke to be the market wage times the time it takes the household to collect 10 kg of the resource. Kumar and Hotchkiss find that when deforestation increases by 1 percent, the time allocated to fuelwood collection increases by 0.6 percent. Assuming that the time spent in fodder and cut grass increases similarly, the authors conclude that the total collection time for all three resources increases by 1.13 hours per day per woman in areas where there is high deforestation. Cooke, using somewhat different estimation methods, similarly finds that when fuelwood and fodder become scarce, that is, when their "shadow price" increases, households spend more time in their collection. Furthermore, she finds that increases in household time spent collecting environmental products come predominantly from *women's* time. Increases in women's collection time account for over 80% of total collection time increase. Further, Cooke (2000) using panel data for the same households finds that household collection time significantly increases with measures of environmental resource scarcity. The household collection burdens are significantly lower in 1997 than in 1982 due to reduced consumption and increased collection from private land. Finally, Ilahi and Grimard (2000), using data from the Pakistan Integrated Household Survey (1991), investigate how access to water infrastructure affects the time women allocate to water collection[4]. Unlike Kumar and Hotchkiss, and Cooke, these authors explicitly allow for a household to meet its demand for this natural resource through private provision and develop a household level measure of access to water infrastructure that is exogenous to the household. They find that as access to water infrastructure deteriorates, on the one hand, the probability that women collect water from a common source decreases. But, on the other hand, time devoted to collection by women who continue to collect increases due to lack of alternatives. The paper does not examine the effect of the change in access to water infrastructure on time allocation decisions by other, non-female, members of the household.

Our paper builds on this literature in a number of respects. First, Kumar and Hotchkiss (1988), Cooke (1998a) and Ilahi and Grimard (2000) focus on a single resource stock—the first two on biomass and the latter on water infrastructure—whereas our study considers stocks of three resources, namely, water, forests and fodder biomass, and time spent in the collection of the respective natural resources. Second, the studies by Kumar and Hotchkiss (1988), and Cooke (1998a) are marred by their reliance on a highly indirect, and clearly endogenous, right-hand side measures of resource availability. Kumar and Hotchkiss (1988) use the time needed to collect a fixed quantity, i.e., 20 kilograms, of fuelwood as their measure of timber scarcity. This measure is clearly endogenous. Similarly, Cooke (1998a) uses the shadow price of the resource as the measure of resource availability. Since, and as noted by Cooke, the shadow price is determined endogenously by the household's choices and depends on the household's preferences and

3 Cooke (1998a) assumes that there are no markets for fuelwood, cut grass, or fodder and therefore market prices for these commodities do not exist. She therefore estimates shadow prices for these commodities.

4 Note that the paper does not look at the change in time allocation consequent upon a change in the quantity of water but only a change in the access to water infrastructure. Households may have to change the amount of time allocated to water collection as the quantity changes, even when there is no change in the water infrastructure.

resource production technology, this measure of resource scarcity is also endogenous[5]. Our study, on the other hand, uses a direct, physical measure of resource availability (see Narain, *et al.*, 2005 for a description of our measure of forest and fodder biomass). Furthermore, and unlike Ilahi and Grimard (2000), we use a measure of water availability and not just access to water infrastructure.

The rest of the paper is organized as follows. Section 2 outlines the theoretical model of household time allocation decisions. This is followed, in section 3, with a description of data. Section 4 presents the empirical strategy for the estimation of the time allocation equations and descriptions of variables used in the estimation, and section 5 the estimation results. The final section concludes with the policy implications of our research.

2. Theoretical Framework

To conceptualize the effect of environmental degradation on time allocation decisions of the household and its members, we draw on the model of home production[6] and time allocation proposed by Becker (1965), and later developed by Gronau (1977).[7] In this model, a representative household, with tastes denoted by $_i$ chooses optimal levels of consumption (c_i), and time spent in leisure by men, women and children (t_m^l, t_f^l *and* t_c^l), $u = u\,(c, t_m^l, t_f^l, t_c^l; a_i)$.

Consumption is generated through a home production function

$$c_i = c\,(x_i, a_i^c, b_i^c, t_f^h, t_c^h; y_i), \qquad (1)$$

where, x_i is a numeraire, market-purchased good, a^c_i is an agricultural product consumed by the household, b^c_i is the amount of a generic environmental product, say firewood, used by the household in the production of c, t_f^h and t_c^h are the total time allocated to home production by female members and children, respectively, and $_i$ is a home production technology parameter.

Agricultural goods can either be bought from the market at price p^a or may be generated by the household's agricultural production function.

$$a_i = a\,(t_m^a, t_f^a, t_{hm}^a, t_{hf}^a, b_i^a; L_i, N_i, FC_i), \qquad (2)$$

where a_i is the household's agricultural output, which, in turn, is either sold or consumed by the household. The household uses its own male labour (t_m^a) and female labour (t_f^a), as well as hired male (t_{hm}^a) and female (t_{hf}^a) labour on its farm. Agricultural output is also a function of the household's land holdings, L_i, its livestock holdings, N_i, and the amount of farm capital owned by

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5 To correct for the endogeneity problem, she estimates the time allocation equations using two-stage least squares (2SLS). Cooke (2000) employs another way of getting around the problem of endogeneity. She uses the own-household-excluded ward-level median for the time it takes to collect one kilogram of fuelwood during the dry season as an exogenous indicator of resource scarcity.

6 Household production theory has been used to model the economic activities of rural households in a wide variety of cultural contexts, especially where household 's time endowments are their primary factor input, and households consume most of their own production outputs (Sills, et al. , 2003).

7 The version presented below is adapted from Ilahi and Grimard (2000) and Kohlin and Parks (2001).

the household, FC_i. Finally, agricultural output depends on the amount of a generic environmental product used in agricultural production, be it water or fodder for the livestock, b_i^a.

The environmental good, b_i, be it for household consumption or an input into production, can be obtained from three sources—the commons (b_i^f), private provision (b_i^p), and the market (b_i^m). Production functions for these three sources are, in turn, given by the following:

$$b^f = f\,(t_m^q, t_f^q, t_c^q \,;\, Q_i), \tag{3}$$

$$b^m = f\,(p^b), \tag{4}$$

$$b^p = f\,(\o_{i,}) \tag{5}$$

where,

$$b^f + b^m + b^p - b^s = b^c + b^a \tag{6}$$

t_m^q, t_f^q *and* t_c^q is the time allocated by the males, females and children of the household to resource collection from the commons, the parameter $_i$ denotes the village-level availability of the resource (e.g., volume of timber and fodder biomass). b^s is the amount of biomass sold, whether obtained from commons or from private lands. Also, p^b is the market price of the resource, and $_{i,}$ is the household-level availability of the resource. The latter, in turn, will be a function of household assets such as its land holdings, number of wells and trees[8] owned by the household, etc.[9] The foregoing analysis of the home production model assumes separability in the labour markets, i.e., markets exist for all the commodities. [10]

Utility is maximized subject to time and budget constraints of the household. Equations (7), (8) and (9) denote the time constraints faced by the male members, female members, and children, respectively, and equation (10) is the budget constraint. We assume that all members have a fixed endowment of time given by *T*.

$$t_m^m + t_m^q + t_m^a + t_m^l = T, \tag{7}$$

$$t_f^m + t_f^q + t_f^a + t_f^h + t_f^l = T, \tag{8}$$

$$t_c^q + t_c^s + t_c^h + t_c^l = T, \tag{9}$$

8 Investments in private provision —like a well or tree —might seem to be endogenous. Following Ilahi and Grimard (2000), we choose not to model these decisions as the choice variables. These decisions are made in the past and are in effect fixed decisions for the time frame relevant to our analysis.

9 Note that we assume that the household does not spend any time collecting resources from private sources as well as from the market. This assumption is partly driven by data constraints and partly from the observation that private sources tend to be either in-house or near the house and typically take less of the households' time.

10 The separability assumption is the distinguishing feature of our study site, Jhabua, which is marked by activelabour markets. On the other hand, studies in rural Nepal by Cooke (1998b) assume that environmental goods are not bought and sold and are only available from household production as there are no markets for these goods.

and,

$$x_i = w_m(t_m^{\ m} - t_{hm}^{\ a}) + w_f (t_f^m - t_{hf}^a) + p^a(a_i - a_i^c) + p^b(b^s - b^m) + v_i, \qquad (10)$$

where, $t_m^{\ m}$ and t_f^m is time allocated by male and female members of the household to market-oriented activities. w_m and w_f is the male and female market wage rate respectively and v_i is unearned income.[11] t_c^s is the time spent in schooling activity by children of the household. Equations (7) - (10) can be combined to obtain Becker's "full income" constraint,

$$x_i + w_m (t_m^q + t_m^a + t_{hm}^a + t_m^l) + w_f (t_f^q + t_f^a + t_f^h + t_{hf}^a + t_f^l) = w_m T^m + w_f T^f + p^a(a_i - a_i^c) + p^b(b^s - b^m) + v_i \qquad (11)$$

The first-order conditions show that time inputs are chosen so as to equate the marginal rate of substitution between leisure and consumption to the shadow wage of biomass collection ($\frac{\partial c_i}{\partial b_i}\frac{\partial b_i}{\partial t_i^q}$), the shadow wage of market time ( ), and the shadow wage of home time

( ). Solving the first-order conditions yields a set of optimum (reduced form) gender-specific

time allocation functions, one each for time devoted to the market-based activity, to resource collection, to household production and to leisure. Algebraic manipulation of the first-order conditions shows that if there is resource scarcity, then the marginal product of resource collection goes down and households allocate labour away from resource collection towards other activities.

$\frac{\partial c_i}{\partial x_i} w$ $\frac{\partial c_i}{\partial t_i^h}$

For the rest of the paper, we will focus on the estimation of the gender-specific time allocation equations—that is, those governing the decision to spend time in resource collection—and will relate these to the stock of natural resources.

$t_i^q = t^q (w, v, a, Q, ø, r, p^b, L, N, FC)$
where $i = m, f$ *and* c

An important issue here is that of intertemporal decision-making. We encounter a two-period problem, where one has to take a decision for the whole year. Households make a saving decision in the resource abundant season (i.e., *kharif*/monsoon); for instance, they graze their animals more during this period instead of stall-feeding them so that they may save/store some fodder collected directly for the relatively scarce (summer/dry) season. Then again, in terms of fuelwood, households spend comparatively more time in resource collection in the scarce season so that they spend less time collecting the resource in the following *kharif* season, which happens to be the prime agricultural season. The opportunity cost of labour is very high in this period as they have plenty of work at hand and little time to spare for resource collection. The savings problem is embedded in the storability of the resource. This in turn has implications for their time allocation decisions in other seasons. This is seen clearly in the case of water. Water is not stored

11 The household receives income from wage labour, exogenous non-wage income sources(vi) from selling agricultural output [p^a $(a^i - a^i)^c$], and natural resources collected from the commons [p^b $(b^s - b^m)$].

by our sample households resulting in increased collection time during scarcity (summer season). Most of our results are explained through the one period model. The result is that there remain some anomalies that cannot be fully understood through the one period model since intertemporal decision-making drives these key results. Therefore, we refer to the "two-period problem" in the text in order to explain these anomalies.

In addition to the two-period problem, there were other puzzles that cropped up during the initial analysis of data which could not be explained using economic indicators alone. For instance, there is a large difference in the determinants of male and female time that cannot be explained using available economic data. This is amply illustrated if one were to look at the disproportionate amount of time that women spend in collecting water as compared to men when availability decreases. This and other puzzles prompted us to take up anthropological inquiry as a tool and search for potential answers in order to augment and inform the quantitative analysis. This paper, therefore, build on the available literature by combining two different techniques of inquiry in an iterative manner. The exchange between the quantitative and qualitative data reflects the iterative nature of field-based research and forms a key part of the study. This so-called "mixed-method" analysis finds favour among a growing number of researchers around the world (see Udri, 2003; Rao and Woolcock, 2004; Rao, 2002; Dreze, 2002; Harriss, 2002; Kanbur, 2001; White, 1997, etc.).

The quantitative analysis forms the point of departure for our qualitative study, which then tries to come up with potential answers for some of the puzzles. The qualitative study serves to complement the quantitative analysis by putting it in a cultural perspective and explaining some of the results in a satisfactory manner. This point is amply illustrated when we consider the quantitative results on water collection. There is a substantial increase in women's water collection time during summer. In order to understand what is happening with water collection, we need to know why such an increase takes place, what the additional water collection time means for other activities, where men figure in the picture, and what the benefits of increasing water collection time are over other options, etc. These questions cannot be answered using quantitative data alone. Therefore, these questions were taken to the field where, through informal discussions and observations in some of our villages, we were able to explain the water puzzle better.

For instance, the gendered variation in water collection, we found, had to do with the following reason. Summer corresponds with scarcity of water resulting in an increase in water collection time for women as they are the primary collectors. Summer is also the time when agricultural activity is at its minimum. Given this scenario, women no longer need to spare time for agriculture. Therefore, the additional time on their hands can now be devoted to water collection. Further, since women as such do not get much employment within or near their village, they are busy mainly in household chores. The additional time in water collection does not really hamper these activities as they are adjusted accordingly. It turns out that buying water is not very viable given the poverty and unemployment in the area.

In terms of using seasonal level data, we employ panel data techniques. Our research shows that the time spent in water collection increases with water scarcity but at a decreasing rate for females and children[12]. It further reveals significant seasonal variation in terms of time spent in resource collection[13]. Since summer is a resource scarce season, it shows a dramatic increase in time spent in resource collection compared to *kharif* and *rabi*. Most of this increased time is spent in water collection and here again women account for most of the increase, spending almost three hours per day per female in resource collection. When it comes to grazing, both male and female grazing time increases with increased availability. Here too seasonality is a factor. With increased availability during *kharif*, households take their animals out for grazing more. The availability of fuelwood, as represented by the per capita total biomass, makes men and women more likely to go for fuelwood collection. At the same time, all the household members are less likely to go for fuelwood collection in *kharif*. The presence of natural resource management initiatives such as community forestry programmes makes women and children more likely to go to collect fuelwood but reduces the time spent in its collection. In a nutshell, we find that time allocated to water collection increases due to the reduced availability of groundwater, whereas the grazing time falls with reduced availability of biomass. Unlike studies by Cooke, and Kumar and Hotchkiss, which find that fuelwood collection time increases with resource scarcity, our study finds that the likelihood to go for fuelwood collection falls with reduced availability of biomass[14].

3. Data and Descriptive Statistics

The data for this study comes from the Poverty and Environment Project, jointly undertaken by Resources for the Future, Washington DC, and the Center for Development Economics, Delhi School of Economics. This data set contains household and village level information on household income, time allocation decisions, and resource availability from 543 households in 60 villages in the district of Jhabua in the Indian state of Madhya Pradesh. Jhabua is a predominantly tribal district located at the western border of the state. It displays agro-climatic conditions that are typical in the semi-arid tropics, namely, rain-fed subsistence agriculture and extensive dependence on natural resources. Of the total land area in the district, 54% is classified as agricultural land, 19% as forestland and the rest as degraded land (Narain, *et al.,* 2005).

Fodder biomass and timber volume have been estimated using remote sensing. Satellite images were used to construct the Normalized Difference Vegetation Index (NDVI)[15] for the areas within and around the 60 sample villages. The NDVI data was combined with data from the Madhya Pradesh Forest Department's forest inventory of 1998 to develop a regression model that uses the NDVI as a predictor of tree biomass (Arroyo-Mora, *et al.,* 2001). Since there were no actual ground measurements of grass fodder biomass for the sample villages, firstly biomass in a subset of the sample villages for 2002 was estimated. This was done by combining

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12 Throughout the paper, the resource collection time represents the time spent collecting a particular resource from the common areas and does not include time spent collecting any resource from the private sources.

13 Cooke (1998a, 1998b, 2000) also highlights the issue of seasonality. Cooke (1998b) finds that increases in household time spent collecting environmental products come predominantly from women's time. This holds even when she accounts for seasonality in resource collection.

14 Cooke (2000) finds a similar result.

15 The NDVI is equal to the difference in near infra-red (NIR) and red (R) light reflectance divided by the sum of these reflectances, that is, (NDVI) = (NIR - R)/(NIR + R), and is commonly used to assess or predict vegetation biomass from remote sensing data.

estimates of grass cover in 0.1-hectare plots of forest and grasslands with measures of grass biomass on a dry-weight basis. As with forest biomass, these ground measurements of grass biomass were combined with the NDVI data to develop a predictive model. Another secondary source of data is village level information on groundwater. This information was collected from the Madhya Pradesh Groundwater Department. The Department, since 1973, monitors the groundwater level thrice yearly (pre-monsoon, post-monsoon and winter) in about 89 villages in the district of Jhabua. Each of these villages represents a micro-watershed that together covers the entire district. The sample of 60 villages for the Poverty and Environment Project was chosen from this list of 89 villages[16].

Our dependent variable in this paper is the time spent by men, women and children in the collection of various natural resources. There are eight resources that are collected "directly" by the household from the commons—water, fuelwood, fodder, wood for construction, *mahua* flowers, *mahua* seeds, gum and *tendu* leaves. The sample households also spend time collecting fodder "indirectly" from the commons by grazing their animals on common land. Therefore, time spent in collection of all resources by men, women and children is the sum total of time spent in collection of all nine resources whether directly or indirectly. Since water, indirect fodder collection, i.e., grazing, and fuelwood are the three main resources collected by our sample households, we only examine the time spent in their collection. Average time spent in water, grazing and fuelwood collection constitutes 96.4 % of total household collection time. The time spent by the household in collection activity is adjusted for the number of members of working age in the household.[17]

Our analysis of the home production model relies on the assumption of separable labour markets, i.e., markets exist for all the commodities. This assumption is also true for the environmental goods such as firewood as it is supported by the data used in this study. In our sample, for example, a large number of households either buy or sell environmental goods (see Table 1). Another measure of market completeness is the availability of market prices for environmental goods. We were able to obtain prices for all environmental products (including manure, dung cakes used as fuel, and *tendu* leaves) quite easily for almost all our villages.

Table 1: Market Participation for Selected Natural Resources

Resource	Number of households, where either production or consumption is positive	Number of households that buy	Number of households that sell	Number of households that either buy or sell
Water	534	81	1	82 (15%)
Fuelwood	513	113	36 140 (27%)	
Fodder	499	338	35	363 (73%)
Others	437	185	83	238 (54%)

Note: Figures in parentheses show the proportion of households that engage in trading.

16 For a detailed description of data, see Narain, et al., (2005).

17 This is done by dividing the time spent by the household in resource collection by the number of men, women and children in the household. Although we do have the information on migration at the seasonal level, we assume the same number of working age members in all the seasons for our analysis.

The collection time differs in different seasons. An agricultural year in Jhabua is divided into three seasons—*kharif, rabi* and summer. *Kharif* corresponds with the monsoon/rainy season and is also the prime agricultural season lasting from June to October. *Rabi* constitutes the winter spanning November through March while the summer/dry season consists of the months of April and May. *Kharif* is the resource abundant season with the availability of water and grass being high. Since it is the primary agricultural season, all members of the household are busy in their field and consequently devote less time to resource collection. In *rabi,* a second crop may be harvested if the rainfall has been good. If not, this is the period when most households start migrating to the adjacent states of Gujarat and Rajasthan for work. The migrants return by the middle of summer to start preparing their field before the onset of rains. The availability of grass, timber biomass and water gradually declines in *rabi,* reaching its lowest by the time summer sets in. Summer corresponds with resource scarcity. Hence, people tend to spend more time in resource collection as compared to other seasons. Summer is also low opportunity cost time for collection activity as employment is hard to find, thus freeing up time for resource collection.

Table 2 shows the average number of hours spent per capita, per male, per female, and per child in the household in collection of various resources. There are 524 households (approximately 96.5 % of our sample) who spend positive amounts of time in resource collection during the survey period. At the household level, resource collection accounts for approximately one and a half hours per capita per day. With an average size of more than 7 for the sampled households, these households spend approximately 10 hours a day collecting resources from the commons. This time however is approximately 5.5 hours a day if time spent collecting water is excluded. This is slightly less than the time spent in resource collection by an average household in rural Nepal—almost 6 hours per day (Cooke, 1998a).[18] In the survey year, sample households spent most of their time in water collection and grazing—around 0.63 hours in water collection and 0.61 hours per day per capita in grazing. Therefore, water collection and grazing appear to be the main activities carried out by the sample households.

At the level of gender, it is evident that women are primarily responsible for the collection of resources. The average time spent per female in resource collection (1.71 hours per day) is almost the double of average time spent per male (0.94 hours per day) in the household. Next to women, children appear to be mainly responsible for resource collection in the household, spending, on average, more than an hour in resource collection per child. Men appear to be mainly involved in grazing animals on the commons, spending around 0.57 hours daily per male member of the household. Out of the total collection time, women spend the maximum time in water collection—1.25 hours per day per female in the household. It is also evident that women mostly collect fuelwood and fodder. However, in contrast to the 3.5 hours per day spent in fuelwood collection by women in rural Nepal, women in our sample spent only 0.4 hours in this activity. Children spend the maximum time in grazing (almost an hour per child per day) out of their total resource collection time.

18 Cooke does not includes time spent in water collection.

Table 2: Hours Spent per Day in a Year in Resource Collection (524 Households)

	All resources	Water	Grazing	Fodder	Fuel wood	Other resources
Collection Time per Capita	1.42	0.63	0.61	0.04	0.13	0.01
Collection Time per Male	0.94	0.24	0.57	0.04	0.09	0.01
Collection Time per Female	1.71	1.25	0.21	0.06	0.20	0
Collection Time per child	1.34	0.30	0.94	0.02	0.07	0.01

Table 3 shows the average number of hours spent per day for the entire year as well as for the seasons. At the seasonal level, households spend more time in overall collection of resources in the summer season as compared to *kharif* and *rabi*. Households spend a lot more time in water collection and a lot less time in grazing in the summer as compared to the other two seasons. This is due to the fact that in the resource-scarce season of summer water scarcity leads households to spend more time in the pursuit of water. At the same time, due to decreased availability of fodder, households also spend less time grazing animals, probably switching to other options. Households also spend more time collecting firewood in *rabi* and summer as compared to *kharif*.

Table 3: Hours Spent per Day during Entire Year and by Season in Resource Collection (524 households)

	All resources	Water	Grazing	Fodder	Fuelwood	Other resources
Collection Time per Capita in a Year	1.42	0.63	0.61	0.04	0.13	0.01
Collection Time per Capita in *Kharif*	1.35	0.47	0.74	0.08	0.06	0
Collection Time per Capita in *Rabi*	1.37	0.58	0.59	0.02	0.18	0
Collection Time per Capita in Summer	1.75	1.20	0.34	0.01	0.20	0.01

Table 4: Number of Households that Collect Various Resources during Year and by Season

	All resources	Water	Grazing	Fodder	Fuelwood	Other resources
Year	524	503	364	76	269	63
Kharif	508	470	347	34	42	5
Rabi	504	472	303	47	184	16
Summer	499	471	196	10	212	37

Although Table 3 shows that the time spent in water collection varies by season, Table 4 shows that the number of households that collect water do not. 503 households collected water during the survey year. However, there are many households that do not collect water from public sources. Since water is an essential commodity for the household, we need to see how these others meet their requirement. Our data shows that 56 households obtain water from private sources such as wells or pumps owned by the household. Around 81 households buy water. The nine households that do not obtain water from any of the three sources mentioned above received water as transfer or gift from neighbours, friends, relatives, etc. Tables 3 and 4 also show that the number of households that graze animals declines from *kharif* to summer (as is the time spent) while the number of households that collect fuelwood increases from *kharif* to summer (as is the time spent).

Table 3 shows that the scenario for the *kharif* and *rabi* seasons remain essentially the same throughout the year. Therefore, we do not present summary statistics for the time spent in resource collection for these two seasons. However, there is a dramatic difference in the summer season with respect to time in resource collection. Table 5 shows the average number of hours spent per day in the summer season in the collection of various resources. During the summer season, time spent in water collection goes up. Even the time in fuelwood collection increases to some extent. However, the time spent in grazing and fodder collection falls due to the decreased availability of fodder in this season. Table 5 also reflects the fact that increased collection time during the summer season is met primarily by women, with the average female in the household spending almost three hours per day in collecting resources from the commons. The increased collection time for women comes mainly from water collection and to some extent from fuelwood collection. The time spent by men and children in resource collection in the summer season remains almost the same as that for the other two seasons.

Table 5: Hours Spent per Day during Summer in Resource Collection (499 Households)

	All resources	Water	Grazing	Fodder	Fuel wood	Other resources
Collection Time per Capita	1.84	1.26	0.36	0.01	0.21	0.01
Collection Time per Male	1.09	0.59	0.36	0.003	0.13	0.01
Collection Time per Female	2.83	2.33	0.14	0.01	0.34	0.01
Collection Time per Child	1.32	0.64	0.52	0.005	0.15	0

Preliminary data analysis shows that the three important resources that are being considered—water, fuelwood and fodder—are treated differently from each other in terms of seasonal variation in time spent in collection. The time spent collecting water increases substantially with scarcity during the summer season. Most of the increase in water collection time can be seen as an increase in women's collection time. These differences can be explained by the presence of markets. Unlike the markets for fodder and fuelwood, markets for water are non-existent or thin at best. 77 households in our sample buy water but the market for water, though it exists, is not fully functional. That is, while calling tankers for water in time of scarcity may be an option, it is not feasible. Firstly, a typical tribal household does not have the money to spend on purchasing water during scarcity. In addition, there are no options in lieu of collecting water. The villages are physically spread out and the terrain is undulating. This coupled with a lack of roads means that water tankers cannot move easily in the village. Another hindrance to the use of tankers as an option is the difficulty in fixing the time of arrival and departure of the tanker so as to suit all the households in the village. Other options such as tap water are beyond the reach and control of the villagers.

Another reason for the additional time spent during summer months by women is that they typically do not migrate as often as men do during summer and are therefore able to devote the additional time to water collection. Preference is given to collection of water rather than buying it from the market due to the fact that there is little or no agricultural work on ones' fields or work in the village in the summer and therefore few opportunities exist for women to work outside the household. The time that would have been spent in income generating activities in other seasons is now spent avoiding extra expenditure on buying water via the additional time spent collecting water at a time when availability is reduced.

The time spent collecting fuelwood also rises with the scarcity of biomass in the summer season but for different reasons. Fuelwood collection is actually more productive during the summer/ dry season when the wood is dry and hence not as heavy as when wet which makes the storability of the wood easier. However, the time spent in grazing mostly declines with scarcity because grazing becomes less productive as the grass biomass dries up.

The most important finding of the quantitative study, which is equally corroborated by the qualitative study, is that there are significant seasonal variations in the collection and use of resources. This finding in turn implies that one needs to conduct the quantitative analysis at the seasonal level as well. Generalizations based on analysis carried out over a year might not be sufficient in themselves to understand the complete picture with respect to time allocation decisions at the household as well as at the gender level.

4. Empirical Strategy and Description of Variables

a. *Empirical Strategy*: Our data on time allocation faces the problem of *censoring*[19], as the dependent variable is zero for a significant proportion of the sample. For instance, there are households in our dataset that do not collect natural resources and therefore report zero hours for the activity. We have used the three commonly used censored regression models, namely, the Tobit model, the Heckman's two-step estimation, and the two-part model to estimate resource collection equations. The determinants of the decision to collect (or not) may differ from those that determine the time allocated to collection. However, the Tobit model assumes that determinants of the decision to collect are identical to the determinants of the time spent in collection. The Heckman's two-step estimation method [20] takes care of this restriction but the estimates obtained

19 Censoring can be addressed by using a Tobit model or a censored regression model (Amemiya, 1984). While OLS parameter estimates for a Tobit model are biased and inconsistent, maximum-likelihood estimates are unbiased and consistent (Maddala, 1983).

20 The advantage of the so-called Heckit model over Tobit is that it controls for individual self-selection into various activities (Heckman, 1976; 1979). For applications of Heckman's two-step estimation method, see Glick (1999) and Skoufias (1993).

are not as efficient as maximum likelihood estimates (Kennedy, 2003) due to collinearity between the explanatory variables in the regression equation and the inverse Mills ratio (IMR) obtained from the first stage selection equation.[21]

Another alternative to the Tobit model is the Two-Part Model, where the determinants of the first stage decision and the second stage decision are not so related. For instance, time allocated to the collection of a particular resource might be independent of the probability that determines the decision to go for its collection. In such a situation, Cragg (1971) proposes several kinds of Two-Part Models, more general in comparison to Tobit, in which the probability of a limit observation is independent of the regression model for the nonlimit data. Of these, we will be employing the Two-Part model with complete dominance for our empirical analysis. In this case, the model can be estimated separately using a Probit for participation and Ordinary Least Square (OLS) for the time allocation equations over participants only[22]. It is a special case of the sample selection model as the errors of the selection and the regression equation are independent of each other. Although we only report the results for the Two-Part model, our results are robust across all three estimation strategies.

Apart from the issue of self-selection, another matter that needs to be addressed is that of seasonality. The descriptive statistics as well as insights from the field show that there are dramatic differences across the seasons in terms of resource collection time by our sample households. Therefore, we carry out the econometric analysis at the seasonal level. The dataset contains the information on choice variables related to resource collection time as well as some of the explanatory variables at the seasonal level, i.e., for *kharif, rabi* and the summer (dry) seasons. In order to take care of seasonality, we employ seasonal dummies in panel regressions. By employing the panel data technique, one can control for unobserved household-specific effects. For the panel regressions, random-effects specification is used since data on most of our explanatory variables has been collected at the yearly level. This technique assumes that unobserved household-specific effects are not correlated with the explanatory variables. In order to compare fixed and random effects specifications, Hausman tests were carried out that fail to reject the assumptions of random effects specification.

21 The Heckman procedure also introduces a measurement error problem because an estimate of the expected value of the error term, that is, IMR is used in the second stage of the regression. In these cases, Heckit estimates are particularly inefficient and the sub-sample OLS (or the Two-Part Model) may be more robust (Puhani, 2000).

22 In general, it is difficult to justify the inclusion of some variables in one equation and not in the other. Therefore, we assume that all the independent variables determine both the decision to collect (or not) as well as the time allocated to collection.

Table 6: Description, Mean and Standard Deviation of Explanatory Variables[23]

S.No	Variable	Description	Mean	Std. Dev.
1	**head_age**	Age of the household head	44.05	12.48
2	**head_edu**	Household head's years of schooling	2.66	4.14
3	**propn_f**	Proportion of adult (15-60 yrs) female members in the household	0.36	0.15
4	**propn_c**	Proportion of children (1-15 yrs) in the household	0.28	0.20
5	**mktdist.agr**	Average distance in kilometers between the village and the nearest crop and market for agricultural inputs	5.06	5.33
6	**mktdist.fwd**	Distance in kilometers between the village and the nearest fuelwood market	1.90	4.15
7	**mktdist.fod**	Distance in kilometers between the village and the nearest fodder market	47.94	87.69
8	**jfm**	Dummy indicating the presence of Joint Forest Management in the village	-	-
9	**Watshd_prog**	Dummy indicating the presence of watershed management program in the village	-	-
10	**biomass**	Per capita availability of total (timber and fodder) biomass in thousand of tones	0.82	1.41
11	**waterscarcity**	Average groundwater depth in meters for kharif, rabi and summer season	5.35	2.43
12	**kharif**	Seasonal dummy for kharif season	0.33	0.47
13	**summer**	Seasonal dummy for summer season	0.33	0.47
14	**rain**	Rainfall measured at the block level in millimeters	390.25	171.29
15	**avgwage**	Average of village level daily male and female wage in rupees	41.81	9.19
16	**land*capital**	Number of hectares of land cultivated times the value of farm capital owned in June 2000 per capita	23194.41	224185.3
17	**pvttree**	Number of all the trees owned by the household in per capita terms in June 2000	4.77	33.82
18	**pvtfwdtree**	Number of babul and low-quality-timber trees owned by the household in per capita terms in June 2000	1.28	8.11
19	**pvtfruittree**	Number of trees, other than fuelwood trees owned by the household in per capita terms in June 2000	3.70	36.41
20	**animal**	Animal holdings (weighted sum of bullocks, cows, buffalo, donkeys, goats and sheep) per capita	0.51	0.41
21	**pvtwell_value**	Per capita value of the private wells owned by the household	2016.33	4034.36
22	**nonwageincome**	Unearned/non-wage income per capita	-271.82	2381.81
23	**price_fwd**	In-village rupee price of fuelwood per kilogram	1.42	0.58
24	**price_fod**	In-village rupee price of fodder per kilogram	3.24	2.06

23 The exogenous variables such as avgwage, price_fwd and price_fod are at the seasonal level.

B. *Description of Variable s*[24]: Table 6 presents the description and summary statistics of the explanatory variables. In our model, the utility function of any representative household depends on technology and preferences (d_i). These in turn are affected by several fixed household characteristics such as proportion of adult female members in the household (propn_f),[25] proportion of children in the household (propn_c),[26] age of the household head (head_age) and educational level of the household head (head_edu) and village characteristics such as distance to the agricultural markets (mktdist_agr), presence of resource management committees such as joint forest management (JFM) (jfm) and watershed management programmes (watshd_prog), and rainfall (rain). The educational level of household head (head_edu) is measured by the number of years of schooling of the head. The household head's education is likely to correlate with the education of other members. Therefore, the variable on education is proxy for human capital. The mean number of years of schooling of the household head is less than three years, which shows the level of illiteracy in the region. jfm and watshd_prog are dummy variables such that they take a value of one if the respective resource management committee is present in the village and a value of zero otherwise. Our data reveals that 27% and 45% of the villages have joint forest management (JFM) and watershed management programmes respectively. rain is the block level rainfall measured in millimeters.

As for the measure of natural resource availability, we have direct measures of environmental quality, namely, availability of forest biomass (rs_for_c) and grass biomass (rs_grs_c) at the village (Q) level. They have been calculated via remote sensing (Narain, *et al.*). However, forest and grass biomass are highly correlated with each other.[27] In order to take care of the collinearity problem, we employ availability of total biomass (lbiomass), which is the sum total of forest and grass biomass as the measure of natural resource availability. The measure of Q is the per capita volume of the total biomass available in a village (in tons). In order to examine the combined impact of resource management programmes like JFM and natural resource availability, we use lbiomass*jfm, which is the product of per household availability of biomass (lrs_bio_h) in the village with the dummy indicating the presence of JFM in the village (jfm).

Apart from the measures of natural resource availability, we also have time series data on groundwater depth in the sampled villages which have been collected by the Madhya Pradesh Groundwater Department that represents Q. The seasonal well depth data obtained for the period 1974 to 2001 has been used to compute the village-level scarcity measure of groundwater. The variable indicating the reduced availability of water is waterscarcity, which is the average of groundwater depths[28] in pre-monsoon, post-monsoon and winter seasons.

In order to take care of seasonality, we employ seasonal dummies *kharif* and summer. *kharif* is a dummy variable taking the value 1 if it is the *kharif* season and zero other wise.

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24 The exogenous variables in time allocation equations for water, grazing and fuelwood contain the resource specific variables.

25 Adult members are the ones falling in the age group of 15-60 years.

26 Children refer to household members that are in the age group of 1-15 years.

27 The multicollinearity problem and its remedy are discussed in Appendix 2.

28 The groundwater depth indicates the reduced availability of water, as this measure is the depth at which water is available in the village well from the ground level after deducting the parapet height.

Similarly, summer is a dummy variable taking the value 1 if it is the summer season and zero o ther wise.[29]

The household may also have planted trees on its private land in the past (pvttree), which can affect the current household-level availability of biomass (ø). The average number of all the trees owned per capita by the household is approximately 5. In order to examine how the household meets the fuelwood needs from its private trees, we divide all the trees owned by the household into fuelwood (pvtfwdtree) and fruit trees (pvtfruittree). We also use the value of wells owned by the household (pvtwell_value) to indicate ø. There are 192 sample households that own private wells.

Other determinants of household and women's time allocation are the opportunity cost of time (w) and unearned income (*v*). The dataset contains information on wage rate variables such as the low skill village level daily wage rates for men and women as well as high skill village level daily wage rates for men. However, these wage variables are highly correlated with each other. Therefore, the average of male and female wage rates (avgwage) has been used for the econometric estimations. Our sample includes many households that do not have men or women who participate in the labour market. This holds true especially in the case of women.[30] Using village level wage rate can overcome the problem of self-selectivity by assuming that every individual is paid equally irrespective of his ability, education or experience. Therefore, this approach is problematic since it implies that the rate of return on human capital investment is zero (Khandker, 1987). However, we can ignore this issue as collection is primarily a low skill task and does not require much human capital investment.

Unearned/non-wage income (nonwageincome) is an integral part of the labour supply model. An increase in unearned income confers an income effect on leisure. The measures of unearned income are income from financial transactions (interest income on financial assets such as deposits at bank or post office, women's savings group, loans given to friends and relatives), rental income and income from transfers (sum of cash and in kind payments received by household from its family, friends, the state, and any NGO in the area).

In addition, we use average distance to the nearest markets for agricultural inputs and outputs (mktdist_agr), in kilometers, to show the level of integration of the local farm economy and hence the demand for labour. Farm labour demand is expected to be high in villages closer to agricultural markets (Ilahi and Grimard, 2000). Another variable that reflects high labour demand is the amount of landholdings (*L*) and the farm capital (*FC*) possessed by the household.[31] land*capital measures the number of hectares of land cultivated times the value of farm capital owned in June 2000 per capita.[32] The livestock holding (*N*) of the household also contributes to the agricultural

29 Rabi is the reference season and is therefore not included in the regressions. The coefficient of kharif/summer tells us the difference in the time spent in kharif/summer as compared to rabi.

30 17.27 % (95 households) of the sample reported as not being employed in any of the off-farm employment, which includes off-farm in village, off-farm off village, and public or private sector job.

31 Our theoretical model assumes that agricultural production depends on the amount of landholdings (L), the farm capital (FC), and the livestock holdings (N) possessed by the household apart from the labour input.

32 The dataset contains information on various types of farm capital equipment possessed by the household such as tractors, bullocks, iron and wooden ploughs, electric and diesel pumps, wells and threshers.

system by providing draft labour and dung that is used as fertilizer (Cooke, 1998a). The variable on livestock holdings (lanimal) is measured by the weighted sum of adult cows, buffaloes, bullocks, donkeys, goats and sheep per capita.[33]

The dataset also contains information on market prices (p^b) of natural resources (excluding water) for all the seasons that determine the market purchases of natural resources. We use the average market prices of fuelwood (price_fwd) and fodder (price_fod) in fuelwood collection and grazing equations respectively. Besides their market prices, we employ distance to nearest fuelwood (mktdist_fwd) and fodder (mktdist_fod) markets in fuelwood collection and grazing equations respectively.

5. Estimation Results

Our objective is to examine the determinants of time allocated to collection of natural resources, and to investigate the association between collection time (the dependent variable) and physical availability of forest, fodder and water. We first report the estimation results for time spent in collection of water by males, females and children in the household (normalized by the number of males, females and children in the household respectively) in Table 7 using the two-part estimation technique[34]. The following Table shows the determinants of the probability of any household member to go for water collection (sel_water_m, sel_water_f, sel_water_c) that is estimated using probit random-effects regressions. The second stage regression (ordinary random-effects) examines the determinants of time spent in water collection by males (lt_water_m), females (lt_water_f) and children (lt_water_c).[35]

33 Following Jodha (1986), it is assumed that a buffalo, a cow, a donkey and a bullock are each equivalent to one animal unit and a goat and a sheep are each equivalent to 0.1 animal units.

34 The results of the Tobit Random Effects model are presented in Appendix 1.

35 The dependent variables as well as the explanatory variables pertaining to resource availability, assets like ownership of land and farm capital, trees and animals have been taken in the log form in order to correct for the non-normality of the residuals.

Table 7: Determinants of Time Allocated to Water Collection by Gender

Estimation Method Dependent Variable	Probit RE sel_water_m	RE lt_water_m	Probit RE sel_water_f	RE lt_water_f	Probit RE sel_water_c	RE lt_water_c
head_age	0.014	-0.007*	-0.015	-0.003	-0.023	-0.008*
head_edu	0.143***	-0.022**	0.011	-0.013**	-0.208***	-0.016
propn_f	-10.352***	0.600*	3.182**	-0.794***	-4.142***	0.630
propn_c	-9.491***	0.874***	2.067***	-0.238	8.916***	-1.178***
mktdist_agr	0.012	0.008	0.038	0.005	-0.039	0.005
Waterscarcity	-6.065***	0.416	-0.688	0.744*	-7.403***	1.588**
Waterscarcity _sq	1.292*	-0.106	0.21	-0.201*	2.253***	-0.407*
watshd_prog	0.265	-0.071	0.433*	0.095**	-1.739***	0.006
Kharif	-0.366*	-0.131**	0.198	-0.046**	-0.045	-0.057
summer	0.988***	0.295***	-0.098	0.430***	0.283	0.441***
rain	-0.002***	-0.001*	-0.002***	-0.000*	-0.004***	0.00001
avgwage	0.01	-0.0003	-0.009	-0.0001	0.003	0.002
land*capital	0.027	0.007	0.032	-0.004	0.018	0.017
pvtwell_value	-0.129***	-0.034***	-0.151***	-0.007	-0.008	-0.003
lanimal	-0.866	-0.151	1.419***	0.005	-0.098	0.009
nonwageincome	-0.0001	-0.00001	-0.0002***	-0.00001	-0.0004**	0.00002
Constant	8.045***	0.663	1.998	0.666	4.131*	-0.424
No. of obs.	1629	232	1629	1234	1629	329
R-sq		0.34		0.20		0.31
Chi-sq	90.91***	119.18***	70.71***	697.03***	98.76***	236.89***

An important variable that determines water collection time pertains to the scarcity measure that has been developed using the seasonal well-depth data. The average groundwater depth (waterscarcity) is highly significant in reducing the probability of men and children going for water collection. However, it significantly increases the time spent by females (lt_water_f) and children (lt_water_c) in water collection. The estimated coefficient of square of groundwater depth (waterscarcity _sq) is also significant and negative in water collection equations for women and children. The estimation results for waterscarcity and waterscarcity _sq show a concave and upward sloping relationship between time spent in water collection and scarcity of water; time spent in water collection increases with scarcity but at a decreasing rate for women and children.[36] These findings imply that with rising scarcity of water there is a reduction in the probability of water collection among men and children, but among those children who go to collect, more time is spent in water collection.[37]

With respect to seasonal variation, the probability of men going for collection increases in summers (summer). All members of the household spend more time in water collection during this season. This maybe due to the fact that summer corresponds to reduced availability and therefore men are more likely to help out in water collection to fulfill household

36 Refer to Appendix 2.

37 This result is similar to the one found by Ilahi and Grimard (2000). As access to water deteriorates, women are less likely to go for water collection but those who continue to collect, maybe due to lack of alternatives, spend more time in water collection

needs.[38] Moreover, since summer is a low opportunity cost time for collection activity with employment scarce, there is scope/possibility for an increase in collection time. At the same time, men and women spend less time in water collection during *kharif* (kharif). Men are also less likely to go for water collection during this season. Since the availability of water goes up during the *kharif* season, households do not have to spend more time collecting water from public sources. At the same time, the opportunity cost of labour is very high during *kharif*. Since it is the prime agricultural season, adult members of the household are mostly engaged in farm activities leaving the responsibility for water collection with the children of the household.

The private source of water (pvtwell_value) significantly reduces the probability of males and females going for water collection as well as reducing the time spent in water collection by men. These findings imply that women, being primarily responsible for water collection,[39] are affected the most in terms of an increase in their water collection time with scarcity. However, their decision to collect water is significantly influenced by the number of wells owned by the household. The presence of watershed management programme in the village (watshd_prog) not only increases the probability of women going for water collection but they also spend more time in collection. Children, however, are less likely to go for collection in these villages. Watershed programmes are likely to increase the groundwater level. Hence, due to increased availability, women can handle water collection on their own while the children can be employed in other activities like grazing.

We now examine the effect of other exogenous variables on water collection time. We find that the presence of adult females (propn_f) in the household increases the probability of females going for water collection while simultaneously reducing the time spent by them in this activity. At the same time, this variable significantly lowers the probability of water collection by males and children. The presence of children (propn_c) in the household increases the probability of children going for water collection while simultaneously reducing the time spent by them on this activity as there are more hands to take care of it. This variable also significantly reduces the likelihood of men going for water collection but raises their collection time; simultaneously this makes it more likely for women to go for water collection.

The amount of livestock holdings (lanimal) significantly increases the probability of women collecting water. This is expected given the fact that water is also collected for livestock. In extreme scarcity, animals may be given a minimal quantity of water at home, just enough to keep them alive. This water mostly comes from the water collected by women. Since women are mainly responsible for water collection, the number of animals in the household would increase the probability that they go for water collection as men look for more productive chores.

The average distance to the nearest agricultural markets (mktdist_agr) that captures the demand for labour in the market significantly reduces female participation in water collection. If the household is in a village that is well connected with agricultural markets, there is an increasing

38 Although ad_01 reflects the reduced availability of water across the villages, the variable that captures this effect over a period of time is the seasonal dummy-**summer**. Male members of the households do respond to the seasonal scarcity of water by significantly spending more time in water collection during the summer season.

39 This is also established in Table 2.

possibility of women of the household working outside in the labour market. An increase in the non-wage income of the household (nonwageincome) reduces the likelihood of women and children going for water collection. The non-wage income of the household captures the wealth effect whereby households are less dependent on water collected from public sources and therefore less likely to go for the same.

We now examine the time spent in grazing by males (lt_graze_m), females (lt_graze_f), and children (lt_graze_c) in the household. The results are reported in Table 8.

Table 8: Determinants of Time Allocated to Grazing by Gender

Estimation Method Dependent Variable	ProbitRE sel_graze_m	RE lt_graze_m	ProbitRE sel_graze_f	RE lt_graze_f	ProbitRE sel_graze_c	RE lt_graze_c
head_age	0.018*	-0.004	0.015	-0.004	-0.011	-0.010***
head_edu	-0.080**	-0.024**	0.037	0.001	-0.224***	-0.016
propn_f	-1.29	0.954**	2.954**	-1.497**	-0.673	-0.577
propn_c	-2.049**	0.590**	0.885	-1.127**	7.904***	-2.142***
mktdist_fod	-0.001	-0.0003	0.005***	-0.001	-0.003	0.0004
mktdist_agr	-0.047	0.01	-0.110***	-0.019	0.081***	0.0003
Lbiomass	-0.131	0.071**	-0.078	0.186***	-0.081	0.044
lbiomass*jfm	-0.027	-0.031***	-0.03	-0.056***	0.043	0.0002
Kharif	0.550***	0.092***	-0.344	0.011	0.504***	0.062**
summer	-0.765***	-0.026	-0.649***	-0.055	-1.312***	-0.155***
avgwage	-0.009	0.002	0.005	0.005	0.002	-0.001
land*capital	0.241***	-0.012	0.128***	-0.007	0.318***	-0.036**
pvttree	-0.055	-0.056	-0.789***	0.05	-0.583	0.002
lanimal	0.894	0.565**	2.902***	0.076	0.334	0.699***
nonwageincome	-0.0001	0.00001	0.0001	0.00003	-0.00004	-0.00003
price_fod	-0.046	0.002	-0.012	0.039**	0.015	0.01
Constant	-3.347**	0.33	-7.678***	0.857	-6.304***	2.464***
No. of obs.	1629	343	1629	134	1629	441
R-sq		0.23		0.34		0.33
Chi-sq	89.09***	55.63***	51.21***	41.10***	120.81***	129.01***

The availability of biomass in the village (lbiomass) increases time spent in grazing by males as well as females though only in non-JFM villages. This increase is explained by the fact that with increased availability of biomass, grazing animals in the commons become a profitable activity as the marginal product goes up.[40] Moreover, time spent by children is not affected significantly with biomass availability because they have to undertake this activity irrespective of the availability as those primarily responsible for this work. However, men and women spend less time in grazing in villages that have JFM and high levels of per-household biomass (lbiomass*jfm). This finding does not imply that villages with JFM have higher biomass availability since the latter has already been controlled for. The presence of JFM might impose restrictions on the households with regard to the time spent grazing in common lands.

40 People in grass biomass rich areas keep more livestock which is also responsible for an increase in the grazing time in these areas.

In terms of seasonal variation, men and children are more likely to go for grazing in *kharif* (kharif) season. Our field enquiries also pointed to the fact that households increase grazing time with availability as they can then save the fodder collected from the commons for the relatively resource scarce (summer) season. All the household members are less likely to go for grazing in summer (summer). While men and children spend increased amounts of time in this activity during the *kharif* season (kharif), the latter allocate less time to grazing during summers (summer). These regression results show that seasonality matters. All the household members are less likely to go for grazing in the summer season as the grass availability goes down and the household prefers to let their animals graze on their own during the day. In *kharif*, men and children are more likely to take their animals for grazing because grazing becomes much more productive when the grass biomass is high due to rains. In summers, however, the picture is very different. Animals are left to 'fend for themselves,' in the sense that animals are fed and watered (by most households) in minimal quantities early in the day (before dawn) and then let loose with all the other animals of the village.[41] Even during summers, someone in the village is always looking out for the animals if not herding them. Another reason for the reduced possibility of household members taking animals for grazing during summer (not as much compared to the agricultural season) is that most of the men folk/adults of working age go out of the village in search of work. This leaves mainly women and children to look after the household.

Another indicator of scarcity of natural resources is market price of fodder (price_fod) that significantly increases the time spent by women in grazing. Since it is expensive to buy fodder from the markets, women have to allocate greater time for this activity. Further, in households in villages that are remote from the fodder market (mktdist_fod), women are more likely to take their animals for grazing in the common lands.

An important variable that affects the grazing time is the amount of livestock holdings possessed by the household (lanimal). The amount of livestock holdings in the family (lanimal) significantly increases the probability of women going for grazing and also increases the time spent in this activity by men and children. Ownership of livestock and grazing activity are positively related to each other.

The sample households also obtain fodder from private sources. Since the amount of fodder obtained from the private sources could be endogenous, we have used a proxy variable, namely, the number of private trees owned by the household (pvttree)[42]. The number of private trees owned by the household makes women less likely to go for grazing in the commons.

In households with more land and farm capital (land*capital), all the household members are more likely to go for grazing, a result that is difficult to interpret. One plausible reason could be that households with higher landholdings are more likely to take their animals along while they work on their farm.

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41 These animals might roam over some distance, the owners being content if they find a source of water and food. However, food and water are again given (in minimal quantities) after dusk when the animals return home. Here 'fend for themselves' means animals are neither fed nor watered from sunrise to sunset (only fed and watered before sunrise and after sunset) and left loose in the village. This means that there is a definite risk that an animal might die of thirst while it is out of the house.

42 The sample households meet their fodder requirements from the private trees in the form of leaf fodder.

The estimation results for time spent in fuelwood collection by males (lt_fuel_m), females (lt_fuel_f) and children (lt_fuel_c) in the household (normalized by the number of males, females and children in the household respectively) are reported in Table 9.

Table 9: Determinants of Time Allocated to Fuelwood Collection by Gender

Estimation Method Dependent Variable	ProbitRE sel_fuel_m	RE Lt_fuel_m	ProbitRE sel_fuel_f	RE lt_fuel_f	ProbitRE sel_fuel_c	RE lt_fuel_c
head_age	-0.003	-0.008	-0.008	-0.004	0.012	-0.017***
head_edu	-0.052	-0.002	-0.077***	0.001	-0.132**	-0.028
propn_f	-1.527	0.428	1.987**	-0.289	1.77	0.035
propn_c	-1.239	0.456	1.242**	-0.112	5.945***	-1.621***
mktdist_fwd	0.005	-0.003	-0.002	0.013*	0.009	0.018
mktdist_agr	0.038	0.012	0.060***	0.008	0.027	0.002
lbiomass	0.331***	0.072	0.225***	0.02	-0.124	-0.008
lbiomass*jfm	-0.01	-0.009	0.061**	-0.018*	0.088**	-0.033*
kharif	-1.119***	-0.096	-1.576***	-0.037	-1.846***	0.050
summer	0.098	-0.006	0.300***	-0.004	0.226	0.006
rain	-0.0003	-0.0001	-0.001	0.00001	0.001	0.0001
avgwage	-0.046***	-0.012	0.012	-0.003	0.014	0.004
land*capital	-0.03	-0.02	-0.027	0.007	0.115**	-0.036
pvtfwdtree	0.179	-0.197	-0.433**	-0.06	-0.308	0.058
pvtfruittree	-0.004	-0.004	0.005	-0.009	0.331	0.168
lanimal	-0.443	-0.073	-0.608	-0.221	-3.348***	-0.006
nonwageincome	-0.00004	-0.000002	-0.0001	0.00001	-0.0001	0.00004
price_fwd	-0.029	0.046	0.194	0.047	-0.805**	0.109
Constant	-1.283	0.814	-3.270***	0.804**	-5.617***	2.139***
No. of obs.	1629	118	1629	344	1629	117
R-sq		0.21		0.11		0.23
Chi-sq	44.43***	14.63	143.45***	18.46	50.99***	22.71

The most important variable in determining fuelwood collection time is the availability of fuelwood as represented by the per capita total biomass (lbiomass). Availability of biomass in the village (lbiomass)[43] increases the likelihood of men and women going for fuelwood collection. An increase in the availability of biomass increases the possibility of households wanting to collect more in order to stock it up or sell it in the market. Since this signifies better prospects for the household, men's collection time in such a case would increase. In villages with higher biomass availability and the presence of JFM (lbiomass*jfm), women and children are more likely to go to the commons to collect fuelwood. But among those women and children who would go, less time is spent in fuelwood collection. This result is in contrast to the conventional thinking which postulates that these institutions impose restrictions on rural households (see Cooke, Kohlin and Hyde, 2006) so that the latter have little or no access to common lands. However, our results pertaining to JFM do not imply that these institutions might be leading to higher biomass availability in the villages as we have already controlled for biomass availability. Therefore, there are two possible implications. On the one hand, it is possible that these institutions allow a larger number of households to access forest land but impose restrictions on these rural households in terms of

43 Increase in the availability denotes a resource rich area and not the increase in availability in any particular season through the year.

the quantity they can collect from the common lands which would reduce the time they spend in the forest in fuelwood collection. On the other, it is possible that they might be benefiting the households such that they end up harvesting the same amount of resources from the commons while spending less time if JFM villages have a larger proportion of fuelwood trees on their common land (Veld, *et al.*, 2006).[44]

The private source of fuelwood as proxied by the number of fuelwood trees owned by the household (pvtfwdtree) reduces the probability of females going for fuelwood collection. Women, as those mainly responsible for fuelwood collection[45], are less likely to go to the commons to collect fuelwood in cases where the household has access to private sources for meeting their energy requirements.

In terms of seasonal variation men, women and children are less likely to go for fuelwood collection in *kharif* (kharif) as it is the prime agricultural season. The entire household becomes busy in agricultural tasks and there is little time left for resource collection activities—again reflecting the high opportunity cost of time for this activity. Moreover, fuelwood is likely to be wet during *kharif* due to rains. This makes it unsuitable for storage and use, hence making fuelwood collection less productive. In the summer season (summer) women are more likely to go for fuelwood collection. Here, more women go for fuelwood collection during summer than men mainly because men migrate out in search of work during this season, leaving women responsible for this activity. Even in households where men do not migrate, they prefer to spend the time looking for work in the village or within the district rather than collecting firewood and other resources. Furthermore, field inquiries show that people spend increased amounts of time in firewood collection during summer mainly to stock up firewood for the *kharif* season. Since women are free from agricultural work in the summer season, they can easily spend time on fuelwood collection after finishing all the household tasks. Children also help out by either collecting fuelwood while grazing the animals or accompanying the women on their collection tours.

The amount of livestock holdings (lanimal) in the family significantly reduces the probability of children going for fuelwood collection. Possession of animals makes a household less dependent on fuelwood from the commons to meet their fuelwood requirements as they can substitute that with dung cakes. *Kande* [dung cakes] is the most common alternative to fuelwood. People use them more in cases of fuelwood scarcity in comparison with other alternatives, as they are stored for such times.

Another variable that reflects the opportunity cost of time spent in water collection is the average daily wage rate (avgwage). It is expected that as the opportunity cost of time goes up, households allocate less time to collection activities and more time to market activities. Regression results show that an increase in the average daily wage rate (avgwage) reduces the probability of men going for fuelwood collection as men are more likely to participate in income generating activities.

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44 We do not have information on the type of trees in the JFM controlled areas as well as some other common sources of fuelwood such as natural forests, plantations, etc. Creating a new plantation can also provide a new source of fuel, thereby increasing the amount of resource harvested in the new area and perhaps decreasing time spent in collection (Linde-Rahr, 2003).

45 This is shown by simple descriptive statistics in Table 3.

In order to capture the opportunity cost of time spent in water collection *vis-à-vis* time spent in own farm agriculture, we use a variable land*capital that reflects the value of the cultivated land and the value of the farm capital possessed by the household. This variable is an indicator of either a demand for labour on the family farm, which would imply a lower probability of going out for other activities, or it could be seen as an indicator of wealth that has the effect of reducing work time in favour of leisure (Ilahi and Grimard, 2000). This variable significantly increases the likelihood of children engaging in fuelwood collection activity as adult members are more likely to work on their own farm. Rainfall at the block level (rain) reduces the probability of women going for fuelwood collection as fuelwood is likely to be wet due to rains making it unsuitable for storage and use.

As the market price of fuelwood (price_fwd) increases, children are less likely to go for fuelwood collection. When the price of fuelwood increases, households are likely to switch to alternatives like dung cakes if the price truly captures the scarcity of fuelwood. Moreover, women from households in villages that are remote from the fuelwood market (mktdist_fwd) are more likely to go for fuelwood collection in the commons.

6. Conclusions and Policy Implications

Our research questions focus on the relationship between scarcity of natural resources and time spent by the household in collection activity at the level of gender. By addressing these research questions, our study contributes to a better understanding of the linkages between poverty and environment from a gender perspective. For instance, it is believed that as the environment is degraded, women who are primarily responsible for resource collection will spend more time in this activity—time that could have been better spent in income-generating activities. Our study shows that women are primarily responsible for the collection of resources—the average time spent per female in resource collection (1.71 hours per day) is almost double that of the average time spent per male (0.94 hours per day) in the household. Out of total collection time, women spend the maximum time in water collection—1.25 hours per day per female in the household. It is also evident that women mostly collect fuelwood and fodder. Hence, gender studies in this sphere have significant theoretical, empirical, and policy implications.

The existing literature on the impact of environmental degradation on time allocation decisions of the households shows that with increase in deforestation, the time spent in the collection of natural resources, such as fuelwood, cut grass and leaf fodder by the households in general, and women in particular, increases (Kumar and Hotchkiss, 1988; Cooke, 1998a). This could be due to the fact that these studies focus on a special peasant agricultural system with little hired labour. However, our study shows that grazing time and the likelihood of going for fuelwood collection increases (falls) with grass and forest biomass availability (scarcity) respectively. Grazing time increases with availability mainly due to the fact that it saves the household its precious stock of fodder (crop residue, grass collected from the commons or fodder bought from the market), which is kept for the resource scarce season. Time, when it comes to fuelwood collection, also shows an increase with availability mainly because firewood can be easily stored and this would save the household time during periods of scarcity or during times when labour may be required for important tasks like agriculture. In addition, firewood if collected in abundance can be easily sold in the market. These results are more indicative of well functioning markets (labour as well as resource) in Jhabua that may be more representative of rural settings in developing countries like India.

Another interesting result that emerges from this study is the differential treatment of water as a resource from other common property resources, namely, fuelwood and fodder obtained through grazing on the commons. Our study finds that the time allocated to water collection increases due to the reduced availability of groundwater, whereas the likelihood of going for fuelwood collection and grazing time falls with reduced availability of biomass. One plausible reason could be that not many households in the sample participate in the buying and selling of water, whereas a very large percentage of sample households engage in fuelwood and fodder trade (Table1). There are no options available in lieu of collecting water, such as tankers and tap water. This makes the opportunity cost of water collection from public sources low. Hence, households spend additional time in its collection as it becomes scarce. In terms of alternatives to fuelwood, sample households have the option to fall back on *kande* (dung cakes), private trees and crop residues. Fodder collection from the commons in the form of grazing is also substituted for fodder purchased from markets, obtained from crop residues, or private trees in the form of leaf fodder. Due to the availability of various substitution possibilities for these two resources, the opportunity cost of time spent in fuelwood collection and grazing is quite high making these households resort to other options in the event of scarcity.

Our research is particularly relevant in the context of the Millennium Development Goals (MDGs) established by the United Nations, specifically MDG 3 (gender equality). MDG 3 aims to promote gender equality by educating women and integrating them into the monetary economy. It states that women have an enormous impact on the well being of their families and societies and yet their potential is not realized because of discriminatory social norms, incentives, and legal institutions. Our study demonstrates that if scarcity leads to households in general, and women in particular, to spend more time collecting natural resources, then improved natural resource management could alleviate poverty by making more time available for income-generating activities. It can also promote gender equality by giving women more economic power. Moreover, an increase in the collection time may force girls to drop out of school in order to assist their mothers in household and other chores, which would in turn hinder their education. Hence, it is possible that improvement in the natural resource base may give girls more time for education.

Our analysis seeks to inform the policy debate on whether, and to what extent, improved natural resource management—e.g., reforestation, regeneration of grasslands, building water-conserving structures, etc.,—can alleviate poverty by affecting the time allocation decisions by households and by women. A recent paper jointly produced by the World Bank, UNDP, DFID, and the European Commission states that “tackling environmental degradation is *an integral part* of lasting and effective poverty reduction” (World Bank, 2002). Our study too supports the view that natural resource management should be mainstreamed into poverty alleviation efforts. That is, if households in general, and women in particular, spend less time in market activities due to scarcity of natural resources, then an improvement in the natural resource base is necessary to free labour for income generating. This is particularly true in the case of water where our sample households spend increased amounts of time in collection in situations of scarcity as represented by the average groundwater depth as well as during the reduced availability season of summer. An important fact to remember here is that while fuelwood and fodder are substitutable and storable commodities, water has few feasible substitutes in our study area. Therefore, this study makes a noteworthy contribution in pointing out the importance of building water conserving structures that would help the rural poor reduce the time cost of the households in general, and women in particular, thus enabling them to participate more often in income generating activities.

A more comprehensive and interdisciplinary understanding of intra-household behaviour with respect to time allocation decisions would increase the likelihood of better policies reaching the people they are intended to affect— policies in the crucial areas of food production, consumption, nutrition, and natural resource management. Since our study shows the presence of well-functioning markets for various resources, it throws up the possibility of future research on the market decisions of households with respect to these resources, especially fuelwood and fodder.

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Appendix 1: Determinants of Resource Collection Time Using Tobit

A1.1: Water Collection

Estimation Method Dependent Variable	TobitRE lt_water_m	TobitRE lt_water_f	TobitRE lt_water_c
head_age	0.038*	-0.01	-0.008
head_edu	0.087*	-0.066***	-0.227***
propn_f	-8.085***	0.37	-0.739
propn_c	-6.832***	0.77	8.337***
mktdist.agr	-0.015	0.022	-0.035
lad_01	4.579	2.171	-3.068
lad_01_sq	-1.963*	-0.574	0.844
watshd_prog	1.600***	0.401**	-0.874**
kharif	-0.602**	-0.105	-0.204
summer	1.775***	1.217***	1.264***
rain	-0.004***	-0.002***	-0.002**
avgwage	0.022	0.006	0.01
land*capital	-0.025	0.02	0.207***
lv_wel_c	0.002	-0.086***	-0.120***
lanimal	-0.402	0.232	-3.118***
nonwageincome	-0.000**	-0.000**	0
Constant	-4.778	-1.132	-3.577
Observations	1629	1629	1629
Chi-sq	167.15***	252.82***	184.95***

A1.2: Grazing

Estimation Method Dependent Variable	TobitRE lt_graze_m	TobitRE lt_graze_f	TobitRE lt_graze_c
head_age	0	0.044***	-0.011
head_edu	-0.126**	0.076**	-0.303***
propn_f	-2.968	7.857***	-1.418
propn_c	-4.243***	-0.186	7.951***
mktdist.fod	-0.003	0	-0.004
mktdist.agr	-0.014	-0.066	0.131***
lbiomass	-0.29	0.118	-0.32
lbiomass*jfm	-0.098*	0.037	0.124*
kharif	0.835***	-0.245	0.649***
summer	-0.863***	-1.019***	-1.861***
avgwage	-0.014	0.015	-0.003
land*capital	0.312***	0.200***	0.323***
la_tree_c	-0.283	-0.611**	-0.425
lanimal	2.061*	-0.697	1.269
nonwageincome	0	-0.000***	0
price_fod	-0.081	0.112	0.089
Constant	-2.164	-14.557***	-6.479**
Observations	1629	1629	1629
Chi-sq	141.60***	90.36***	229.26***

A1.3: Fuelwood Collection

Estimation Method Dependent Variable	TobitRE lt_fuel_m	TobitRE lt_fuel_f	TobitRE lt_fuel_c
head_age	-0.007	-0.013*	0.009
head_edu	-0.081	-0.078***	-0.155***
propn_f	-1.912	1.984**	2.414
propn_c	-1.341	1.110*	6.844***
mktdist.fwd	-0.006	0.015	0.024
mktdist.agr	0.087	0.065***	0.043
lbiomass	0.676***	0.231***	-0.148
lbiomass*jfm	-0.041	0.044	0.102**
kharif	-2.001***	-1.554***	-2.451***
summer	0.112	0.316***	0.448
rain	-0.001	-0.001	0.001
avgwage	-0.099***	0.006	0.007
land*capital	-0.087	-0.013	0.153***
pvt_fwdtree	0.226	-0.557***	-0.517
pvt_fruittree	0.109	0.035	0.532*
lanimal	-0.78	-0.914*	-5.070***
nonwageincome	0	0	0
price_fwd	0.098	0.199	-1.019***
Constant	-2.739	-3.158***	-6.750***
Observations	1629	1629	1629
Chi-sq	54.62***	164.97***	69.30***

APPENDIX 2

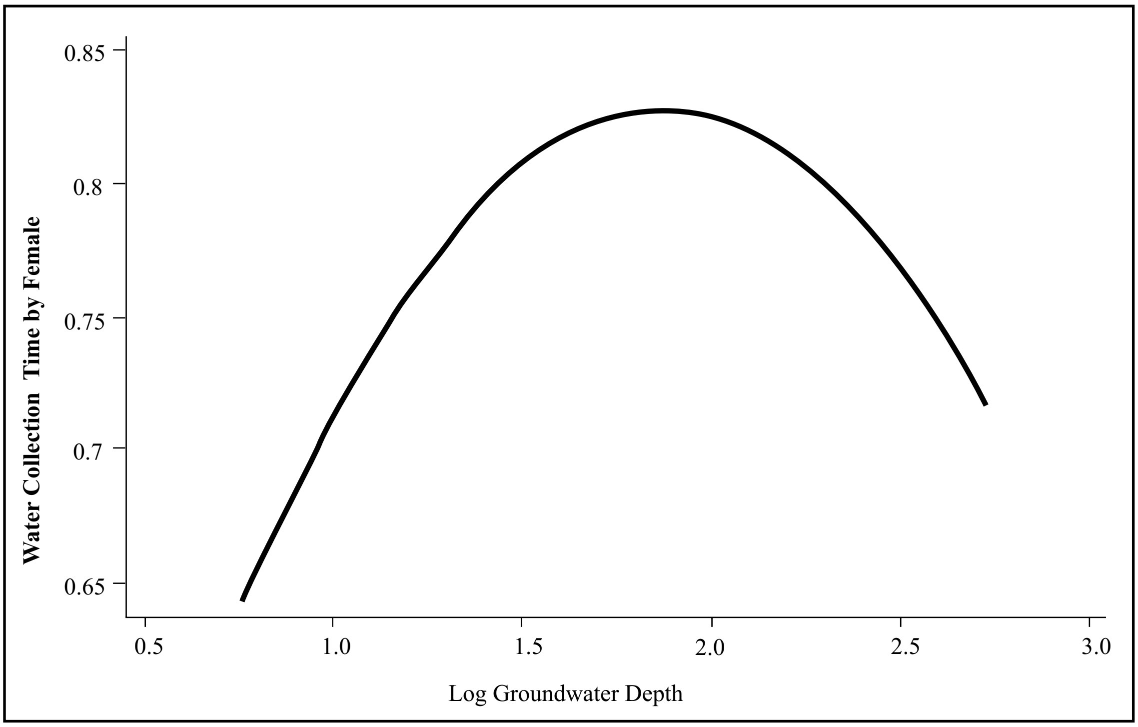

Figure A.1: Relationship between Water Collection Time by Females, Groundwater Depth and Depth Square

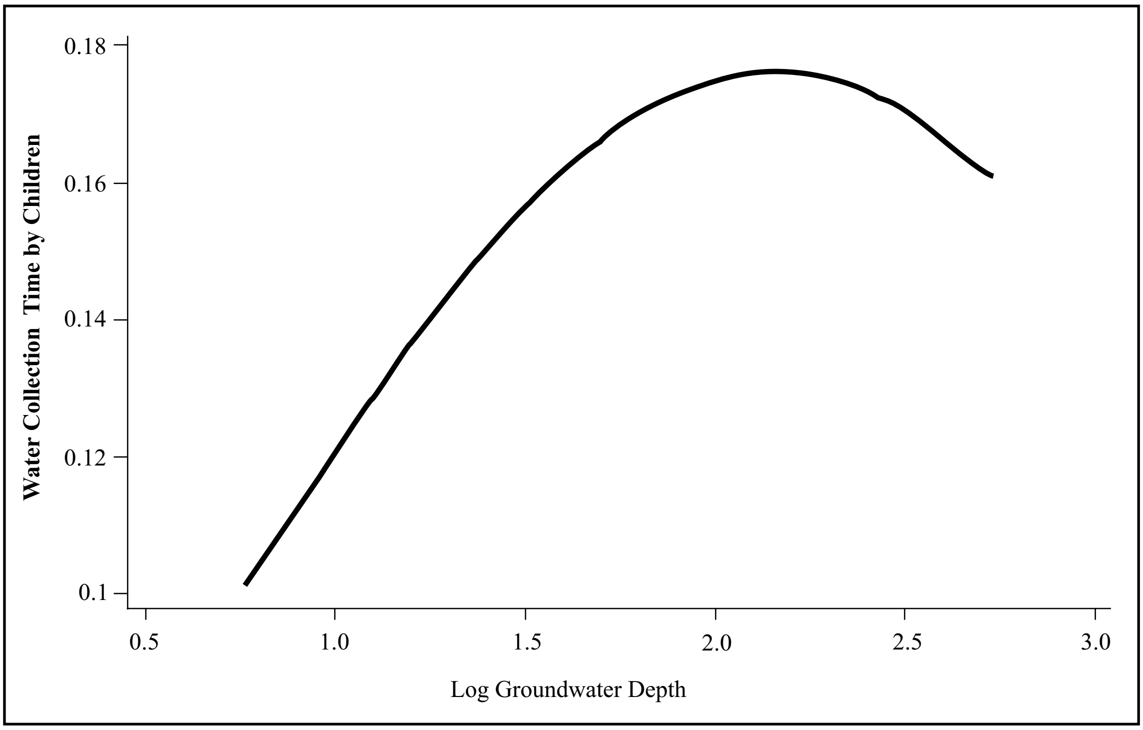

Figure A.2: Relationship between Water Collection Time by Children, Groundwater Depth and Depth Square

APPENDIX 3: REGRESSION DIAGNOSTICS

Regression diagnostics is done to explore how well the existing data meets requirements of the underlying regression techniques. All the requirements (or assumptions) discussed below can cause problems in estimating the regression coefficients if they are violated.

A.3.1 Unusual and Influential Data [46]

There are three ways an observation can make a substantial difference in the regression results.

Outliers: In linear regression, an outlier is an observation with large residual. For this observation, the value of the dependent variables is unusual given the value of independent variables. It may indicate sample peculiarity or data entry error.

Leverage: A leverage point is an observation with extreme value of the independent variable and can have an effect on the estimated regression coefficients.

Influence: An observation is said to be influential if removing the observation substantially changes the estimates of coefficients. It can be thought of as the product of leverage and outlierness.

On this basis, we examined different measures of leverage and influence to check for potential outliers. These measures included examining of standardised residuals, leverage, cooksd, DFITS and DFBETA. The dataset was examined carefully and was cleaned particularly with regard to variables related to water collection. There were a lot of problems that were resolved like giving uniform quantity codes, detection of potential outliers in terms of time spent in water collection as well as amount of water collected and purchased. Even for fuelwood and fodder, certain households emerged as outliers with regard to collection time as well as amount of resources collected and consumed from the commons. Seven households were dropped from the original set of 550 households due to these problems.

A.3.2: Heteroscedasticity

Since we are dealing with cross section data, it can be prone to the heteroscedasticity problem. For instance, survey data are often collected using clustering where some groups are deliberately over sampled. Such sampling strategies introduce some degree of heteroscedasticity of the error terms. In the presence of heteroscedasticity, we get inconsistent estimates when the usual maximum likelihood method is employed (Melenberg and Soest, 1996). Heteroscedasticity leads to bias in the estimates of the regression coefficients, but nothing can be said about the direction of the bias (Maddala, 1983). Any of the three tests can be used to test for this problem— the Lagrange Multiplier (LM) test, the Likelihood Ratio (LR) test or the Wald test. This problem can be overcome by estimating the heteroscedastic version of the Tobit model after making a reasonable assumption about the nature of heteroscedasticity (Greene, 2003)

Another way to handle the problem of heteroscedasticity is to use robust standard errors. Under heteroscedasticity, the OLS estimates, although unbiased, are not efficient; that is, they do not

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46 Refer to http://www.ats.ucla.edu/stat/stata/webbooks

have minimum variance. Hence, the standard errors are biased that leads to bias in the test statistic. Robust standard errors by relaxing the assumption that errors are independently and identically distributed are trustworthy. They do not change the coefficient estimates but the test statistic gives more accurate p-values as the standard errors are changed. In a survey data, error terms will not be independently and identically distributed because observations (e.g., households) selected within the cluster tend to be similar than across the clusters.

The dataset used for this study is essentially primary data collected from the village and household level survey. As described in the section on 'Data and Descriptive Statistics', a random sample of households was generated through a *two-stage sampling design*, where in the first stage, a stratified random sample of villages was generated and in the second stage, a stratified random sample of households was generated by oversampling of landless and land-rich households within the villages (Narain, *et al.,* 2005). This implies that error terms for households within any given village are likely to be correlated, giving rise to the problem of heteroscedasticity. Since we use the STATA version 8.0 for the econometric estimations, we employ survey commands to analyze this dataset. Use of survey commands in STATA produces robust standard errors by making sure that observations are weighted and standard errors are corrected to account for the survey design.

A.3.3 Multicollinearity

Multicollinearity refers to the existence of a perfect or exact linear relationship among some or all-explanatory variables of a regression model. As the degree of multicollinearity increases, the regression model estimates of the coefficients become unstable and the standard errors for the coefficients can get wildly inflated. Multicollinearity can be detected by examining some rules of thumb. Firstly, a pair wise correlation coefficient in excess of 0.8 (absolute value) is indicative of multicollinearity. Another way to detect muticollinearity is to check for the variance—inflating factor (VIF)—that gives the speed with which variances and covariances increase.

As the correlation coefficient between the explanatory variables x and z, r_{xz} approaches 1, VIF approaches infinity. As a rule of thumb, the value of VIF greater than 10 indicates the presence of multicollinearity.

The problem of multicollinearity is particularly relevant when using the Heckman's sample selection model. As discussed before, Heckit estimates are particularly inefficient due to the collinearity between the explanatory variables in the regression equation and the inverse Mills ratio (IMR) obtained from the first stage selection equation. A further step to detect multicollinearity is to calculate R^2 of the regression of the inverse mills ratio on the regressors of the outcome equation or by calculating the corresponding condition number. If the condition number exceeds 20, the TPM (or subsample OLS) is more robust (Puhani, 2000).

All the rules of thumb discussed above indicated the presence of multicollinearity in our dataset, following which certain variables were dropped. For instance, the wage rate variables such as the low skill village level daily wage rates for men and women as well as high skill village level daily wage rates for men are highly correlated with each other (Table A.1). Therefore, the average of male and female wage rates was used for the econometric estimations. The variable on landholdings and farm capital owned by the household were also found to be collinear with each other and were hence combined into one variable (Table A.2). Furthermore, the resource availability variables (timber/forest and grass biomass measures) and their quadratic counterparts were found to be highly correlated with each other, following which only the total biomass was used as an explanatory variable (Table A.3).

After accounting for all the changes mentioned above, the variance-inflating factor (VIF) was again calculated and was reasonably below the maximum limit of 10 (Table A.4). The condition number was also estimated and was found to be below 20.[47]

A.3.4 Non-normality

If the underlying disturbances are not normally distributed, then the maximum likelihood estimates are inconsistent (Greene, 2003). Therefore, we used the log of dependent variables (time spent in collection of various resources) as well as the explanatory variables pertaining to resource availability. Assets like ownership of land and farm capital, trees and animals have been taken in the log form in order to correct for the non-normality of the residuals. Furthermore, we used a kernel density estimate to examine the normality of Tobit residuals. Under this procedure, one can see the kernel density plot along with normal density overlaid on it to examine the extent of departure from normality. We tried this technique for all the gender-specific resource collection equations and the corresponding residuals showed no deviation from normality. Figure 5.2 shows the kernel density plot of the Tobit residuals where time spent in water collection by males is the dependent variable.

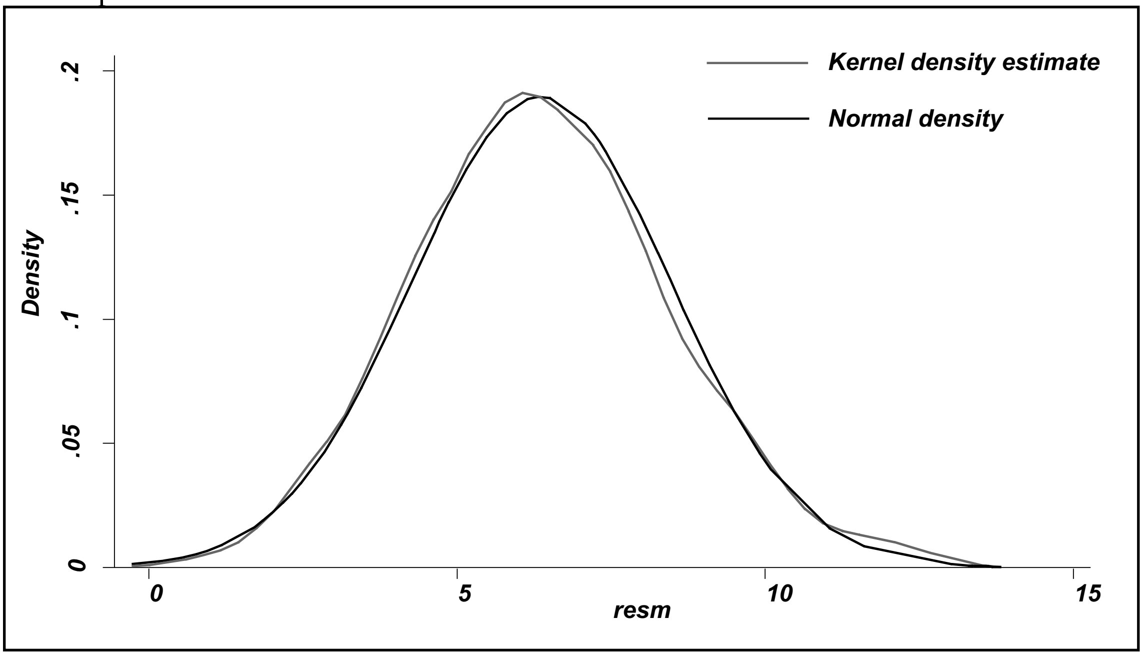

Figure A.3: Kernel Density Plot vs. Normal Density

47 In case of water collection equations, we have used the log of groundwater depth as well as its quadratic term as the coefficient of groundwater depth is significant only in this specification. This leads to the problem of multicollinearity. The most important consequence of multicollinearity is that resulting estimators are inefficient due to high standard errors, making the t-ratios statistically insignificant. However, our results show that the collinear variables are highly efficient as the t-ratios are statistically significant. Furthermore, we employ Two-part model, which is more robust in the presence of multicollinearity.

Table A.1: Correlation Matrix to Detect Multicollinearity in the Wage Rate Variables

	p_ls_m	p_ls_f	p_hs_m
P_ls_m	1	-	-
P_ls_f	0.89	1	-
P_hs_m	0.67	0.61	1

Table A.2: Correlation Matrix to Detect Multicollinearity in the Variables Pertaining to Landholding (a_lct_c) and Farm Capital (v_cap_c) of the Household

a_lct_c	v_cap_c	
a_lct_c	1	-
v_cap_c	0.60	1

Table A.3: Correlation Matrix to Detect Multicollinearity in the Resource Variables

rs_for_c	rs_for_sq_c	rs_grs_c	rs_grs_sq_c	
rs_for_c	1			
rs_for_sq_c	0.9069	1		
rs_grs_c	0.5849	0.4107	1	
rs_grs_sq_c	0.3889	0.2766	0.8898	1

Table A.4: Variance Inflation Factor of Explanatory Variables

Variable	VIF	1/VIF
land*capital	2.12	0.47
Lanimal	2.09	0.48
propn_c	1.84	0.54
propn_f	1.74	0.57
Rain	1.51	0.66
Lbiomass	1.51	0.66
pvt_fruittree	1.43	0.70
lbiomass*jfm	1.39	0.72
mktdist.agr	1.35	0.74
Kharif	1.35	0.74
Summer	1.34	0.75
price_fwd	1.27	0.79
pvt_fwdtree	1.25	0.80
Avgwage	1.17	0.85
head_edu	1.17	0.86
head_age	1.16	0.86
nonwageincome	1.1	0.91
mktdist.fwd	1.09	0.92
Mean VIF	**1.44**	