Chapter 15

Nontimber Forest Products in the Rural Household Economy

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Among the multiple outputs of forests, the category labeled nontimber forest products, or NTFPs, has drawn increased policy and research attention during the past 20 years. NTFPs have become recognized for their importance in the livelihoods of the many relatively poor households who live in or near forests, especially in the tropics. Policy concern about NTFPs takes two forms. On the one hand, collection of relatively high-volume, low-value NTFPs, such as fuelwood, fodder, and mulch, has raised concerns about degradation of the forest resource, potentially resulting in hardships for households and negative environmental externalities. On the other hand, collection of relatively high-value, low-volume NTFPs, such as specialty food products, inputs to cosmetics and crafts, and medicinal plants, has drawn interest as an activity that could raise standards of living while being compatible with forest conservation. Addressing these policy concerns requires an improved "understanding of how households interact with natural resources and how one can affect household behavior in desired ways" (Ferraro and Kramer 1997: 207).

In this chapter, we show how both types of NTFPs and related concerns can be understood and evaluated in the household production framework. We illustrate this with two case studies, from the distinct cultural and historical contexts of the Western Ghats of India and the Brazilian Amazon. Our approach is first to clarify objectives, constraints, and conditioning factors using household production theory, and then to estimate econometric

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models consistent with that theory and feasible given available data. This raises modeling issues such as the implications of missing or incomplete markets, the relation of other household activities to NTFP collection, and the representation of heterogeneity across households. Appropriately specified models can provide insight into the role of NTFPs in the rural household economy (Pattanayak and Sills 2001), identify policy levers (Lele 1993), and serve as the building blocks for valuation of local forest access (Pattanayak et al. [forthcoming]) and policy simulations (Bluffstone 1995).

1. NTFP LITERATURE

NTFPs include a wide range of subsistence and commercial products (Neumann and Hirsch 2000, Pérez and Arnold 1995). Although much of the literature focuses on products collected from natural forests in developing countries, NTFPs are also produced in plantations and agroforestry systems (see chapter 16) and in developed countries (Jones et al. 2002). Fuelwood is probably the NTFP collected in greatest volume. In fact, fuelwood and charcoal are often placed in a category of their own, with other NTFPs relabeled as nonwood forest products (NWFPs). These include rattans and bamboos; edible fruits, nuts, and other foods; medicinal plants; resins and latex; wildlife and derivative products; and cultural, religious, and aesthetic commodities (Thandani 2001). The Food and Agriculture Organization of the United Nations estimates that approximately 150 of these NWFPs are "significant in terms of international trade" (FAO 2002), some as traditional commodities (e.g., rattan) and some as "green" products marketed as environmentally friendly (e.g., Brazil nuts). While products that enter formal international markets are easiest to quantify, NTFPs are also known to play a critical role in household subsistence and local and regional markets. For example, FAO (2002) asserts that "80% of the population of the developing world use NWFPs for health and nutritional needs." Byron and Arnold (1999) emphasize that the exact nature and degree of forest dependence varies widely across regions and households. Here, we review three prominent strands of the literature on forest dependence.

1.1 Local Value of NTFPs

Many researchers have sought to quantify the value of NTFPs. Tewari (2000) reviews the motivations and policy implications of these valuation efforts, and Wollenberg (2000) reviews the methodological challenges of obtaining accurate data on quantities and prices. NTFP value can be calculated per hectare of forest (returns to land) or per household (returns to

labor). For the first, researchers typically combine botanical or ethnobotanical information with market price data to find the potential value of NTFP production (Godoy and Bawa 1993, Peters et al. 1989). For the second, researchers (a) track small samples of households with frequent visits to record quantities and prices, (b) rely on respondent recall of quantities and prices in household surveys, or (c) elicit values directly with stated preference methods (see Shyamsundar and Kramer [1996] and chapters 17 and 18). Recent studies that carefully tracked household income conclude that NTFPs contribute between 10% and 60% of full income (Cavendish 2000, Kvist et al. 2001, Reddy and Chakravarty 1999). This contribution varies substantially across households, which is the theme of the next strand of literature.

A common hypothesis is that poorer households are more dependent on the forest (Godoy et al. 1995, Reddy and Chakravarty 1999). The relationship between NTFP collection (quantities or gross value) and socioeconomic characteristics including income or wealth has been analyzed most often with cross-tabulations and graphical methods (Bahuguna 2000, Cavendish 2000, Godoy et al. 1995, Hegde and Enters 2000, Lele 1993, Takasaki et al. 2000). Econometric approaches are discussed in section 2.4. Many of these studies find that poor households depend *relatively* more on NTFPs, conditional on an array of other socioeconomic and geographical characteristics. Findings regarding absolute dependence on NTFPs vary, as does the pattern across middle- and high-income households. Takasaki et al. (2000) use participatory rural assessment methods to categorize Amazonian households by specific types of wealth. They contend that not only the level but also the type of wealth determines how people use the forest and hence their dependence on NTFPs.

The common finding that the poor depend relatively more on NTFPs raises questions about the role of NTFPs in economic development. In the early 1990s, there was great interest in NTFPs as a basis for sustainable development (e.g., Nepstad and Schwartzman 1992, Plotkin and Famolare 1992). More recently, the economic potential of NTFPs has been sharply debated in the literature (Pérez and Byron 1999), with some authors arguing that the role of NTFPs as engines of local development has been greatly exaggerated (Southgate 1998, Wunder 2001). Much of the empirical literature concludes that NTFPs are neither the main driver nor an impediment to development, but rather that they play an important supplemental or fallback role (Godoy et al. 2000, Pattanayak and Sills 2001). In this capacity, NTFPs are seen as supporting the economic development process by serving as a safety net for households entering new economic activities and markets (Byron and Arnold 1999). To better understand this role, we turn next to a conceptual framework of household behavior.

2. HOUSEHOLD PRODUCTION THEORY

Household production theory has been used to model the economic activities of rural households in a wide variety of cultural contexts, especially where households' time endowments are their primary factor input, and households consume most of their own production outputs. Singh et al. (1986) remains the basic reference for agricultural household production models. Hyde and Amacher (1996, 2000) argue for wider application to forestry issues and report such applications to fuelwood. The basic theory posits a household that combines the time endowments of its members with other variable and fixed inputs (including available forest resources) to produce a utility-maximizing bundle of goods, subject to technology, budget, and time constraints.

2.1 Agrarian Households on the Forest Edge

For purposes of this chapter, we present a generic model of a typical agrarian household living on the forest margin (equation 15.1). This household engages in agriculture (A) and collection of NTFPs (F). We assume complete markets for agricultural products and for market goods (M), but incomplete markets for NTFPs and labor. Thus, the amount of labor and leisure available are constrained by household time (T), and cash expenditures are constrained by the value of agricultural output plus any exogenous income (I) such as remittances. The household seeks to maximize a single utility function, which depends on consumption of agricultural goods (A_H), market goods (M_H), forest goods (F_H), and home time (T_H, including leisure, child care, etc.). Household utility is conditioned on preferences (Φ).

$$
\begin{aligned}
&\max U(A_H, M_H, F_H, T_H; \Phi) \\
&s.t. \\
&(1) T \geq T_H + T_A + T_F \\
&(2) A = a(T_A, F_A, M_A; \Psi) \\
&(3) F = f(T_F; B, H, \Psi) \\
&(4) F \geq F_H + F_A \\
&(5) P_A(A - A_H) + I \geq P_M(M_H + M_A)
\end{aligned}
\qquad 15.1
$$

where the constraints apply to (1) household time, (2) agricultural production, (3) nontimber forest production, (4) forest output allocation, and (5) budget. The choice variables are T_H, T_F, M_A, M_H, F_H, F_A, and A_H.

Agricultural production is a function (a) of household time allocated to agriculture (T_A) and other inputs collected from the forest (F_A) or purchased in the market (M_A), conditioned on fixed household production endowments (e.g., land, livestock) and technology (Ψ). Forest production (f) is also conditioned on fixed production endowments. However, we assume that it does not compete with agriculture for land, but rather takes place in public forest, conditioned by its biophysical state (B) and household knowledge of the forest (H). The only variable input in forest product collection is household time (T_F). Forest products are either consumed (F_H) or used as inputs to agriculture (F_A).

To write the Lagrangian function, we combine constraints 3 and 4, resulting in four constraints with four Lagrangian multipliers ($\mu, \gamma, \delta, \lambda$) or shadow values (equation 15.2).

$$\begin{aligned}\ell = {} & U(A_H, M_H, F_H, T_H; \Phi) + \mu(T - T_H + T_A + T_F) + \\ & \gamma(a(T_A, F_A, M_A; \Psi) - A) + \delta(f(T_F; B, H, \Psi) - F_H - F_A) \\ & + \lambda(P_A(A - A_H) + I - P_M(M_H + M_A))\end{aligned} \tag{15.2}$$

The seven choice variables (equation 15.1) and four constraints result in eleven first-order conditions (FOC). To conserve space, we only present the FOC with respect to the three choice variables directly related to forest production and consumption decisions, T_F, F_H, and F_A:

$$\begin{aligned}\frac{\partial \ell}{\partial T_F} &= -\mu + \delta \frac{\partial f}{\partial T_F} = 0 \\ \frac{\partial \ell}{\partial F_H} &= \frac{\partial U}{\partial F_H} - \delta = 0 \\ \frac{\partial \ell}{\partial F_A} &= \gamma \frac{\partial a}{\partial F_A} - \delta = 0\end{aligned} \tag{15.3}$$

Algebraic manipulation of the FOC yields the following results (equation 15.4). First, households allocate their time such that the shadow value of time (μ) is equal to the marginal utility of NTFPs obtained by allocating more time to collecting. This is the familiar proposition that marginal cost equals marginal benefit applied to forest collection. Second, the marginal utility of increased agricultural production arising from inputs of forest products must equal the marginal utility of household consumption of forest products. This condition indicates how households allocate forest production between household consumption and agricultural inputs. Finally, this second condition implies that the shadow value of time must also equal the marginal

utility of increased agricultural production due to forest inputs obtained with more time spent collecting.

$$\mu = \delta \frac{\partial f}{\partial T_F} = \frac{\partial U}{\partial F_H} \frac{\partial f}{\partial T_F}$$
$$\frac{\partial U}{\partial F_H} = \gamma \frac{\partial a}{\partial F_A} \Rightarrow \mu = \gamma \frac{\partial a}{\partial F_A} \frac{\partial f}{\partial T_F} \qquad 15.4$$

Note that the shadow value of time depends on the parameters of both the utility function and the production functions. Further, the other FOCs would show that the marginal utility of increased agricultural production (γ) is related to the shadow value of income (λ) and consequently to prices and exogenous income. In fact, the shadow values, which are internal to each household, depend on the full set of exogenous variables. As a result, collection, consumption, and the derived demand for labor are also functions of all exogenous variables in the system. This dependence of production decisions on preferences and endowments is termed nonseparability in the household production literature and results whenever key markets are missing or incomplete (Sadoulet and de Janvry 1995).

2.2 Incomplete Markets

To further explore the relationship between nonseparability and incomplete markets, we turn to a graphical treatment. Consider panel A of figure 15.1, representing an individual household's demand (WTP) for a NTFP and two possible household supply curves, or marginal costs of production. If a market for the good exists, the price (P) is exogenous to the household. If the household has high production costs (MC″) relative to P, it will not produce and will purchase the amount Qd. If the household has low production costs (MC′), it will produce Qp′, of which it will consume Qd and sell Qp′ – Qd. In either case, demand is set where WTP equals P. The production level is independent of demand and is established where MC equals P (the profit- maximizing solution). Of course, demand depends on the income generated by production. However, household decisions can be modeled recursively, with production decisions treated as if they were made prior to and independent of consumption decisions (separability).

The usual case for households living on the forest margin is somewhat incomplete or imperfect markets (see Carter and Yao 2002 for argument that this is generally true of rural markets and Behrman 1999 for empirical tests). Following Sadoulet and de Janvry (1995), this can be conceptualized as price bands for the sale and purchase of goods. That is, households can usually purchase at some—perhaps very high—"buyer price" (P_b). Likewise,

households can usually sell at some "sale price" (P_S), although it may be so low that it is irrelevant. There are both spatial (e.g., distance to market) and household-specific (e.g., connections to traders) reasons for the transactions costs (t) that create these price bands. As a result, each household faces different price bands in addition to having unique demand and supply functions.

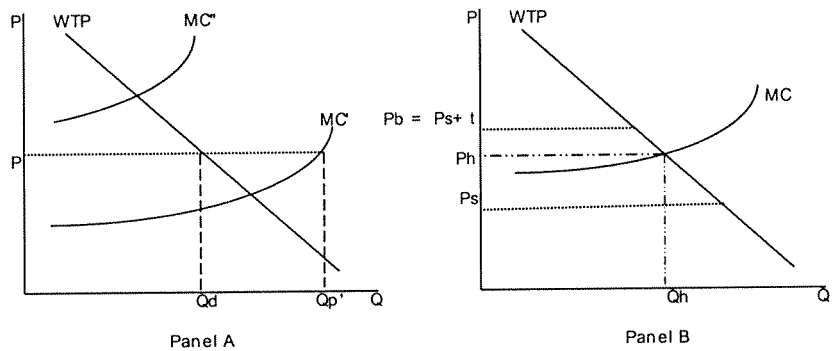

Figure15.1. Household production and consumption of NTFPs

Consider a household producing an NTFP with the WTP and MC curves shown in panel B of figure 15.1. When the intersection of WTP and MC occurs above P_S and below P_b, the household decision about the quantity to collect and consume (Q_h) is determined jointly with a household-specific shadow price P_h (δ in the conceptual model). Both depend on the parameters of household utility (Φ) and household production technology (Ψ, *B, H*). The same holds true for inputs whose demand derives from this household market for NTFPs, such as labor or collection trips. Finally, note that variation in household supply and demand means that some households may still base their production and consumption decisions on the market price if the intersection of WTP and MC falls either below P_S or above P_b. Thus, even when some households are observed to participate in the market, it may be incomplete for others.

2.3 Dynamics of Forest Collection

Thus far, we have presented a static model, with only one time period. However, much of the interest in NTFPs stems from the link between current behavior and future resource conditions. Consider a two-period model, in which households maximize the sum of current and expected future utility, discounted by ϕ (equation 15.5). In the second period, forest production

depends on household knowledge of the forest, which in turn depends on time spent in the forest (learning) during the first period (Pattanayak and Sills 2001). In addition, the quality of forest stocks in period two are affected by the aggregate amount collected by all households during period one (ΣF_I). If access to forest land is privately (or community) controlled, the household (or community) can set ΣF_I.

$$\begin{aligned} &\max U_1(A_{H_1}, M_{H1}, F_{H_1}, T_{H_1}; \Phi) + \\ &\quad \varphi E\{U_2(A_{H2}, M_{H2}, F_{H_2}, T_{H2}; \Phi)\} \\ &s.t. \\ &(3.2)\ F_2 = f_2[T_{F2}; B_2(\textstyle\sum F_I), H_2(T_{F1}), \Psi] \end{aligned} \qquad 15.5$$

The household is also subject to constraints 1 through 5 for period 1 and constraints 1, 2, 4, and 5 for period 2 from equation 15.1.

If we redrew figure 15.1 for period two, the marginal cost curve (MC_2) would shift up if forest stocks had been degraded by collection in the first period.[1] Conversely, if increased forest knowledge more than offsets any forest degradation, MC_2 would shift down. In either case, P_{H2} and Q_{H2} would also adjust. Consideration of these impacts changes the marginal conditions for the first period. For example, time would be allocated such that its shadow value is equal to the *net* contribution of collection time to utility, through increased knowledge as well as increased production (equation 15.6). Households will also consider impacts of current collection on future biophysical conditions when they control access to the forest and hence can determine ΣF_I.

$$\mu_1 = \delta_1 \frac{\partial f_1}{\partial T_{F1}} + \delta_2 \frac{\partial f_2}{\partial H_2} \frac{\partial H_2}{\partial T_{F1}} \qquad 15.6$$

2.4 Model Specification

The household production framework described above gives the analyst multiple options for empirical estimation: the dependent variable may be NTFP production, consumption, marketed surplus, or labor allocation. Estimation results can provide insight into the behavior of households, including the determinants of forest use, the distribution of forest use across households, and responses to potential policy interventions. In the case of complete markets, specification would follow standard production or consumption theory, with prices and income playing key roles. However, as

argued above, the more common case is imperfect markets. Here, we review the specifications and findings of previous empirical work.

2.4.1 Market Assumptions

In much of the literature on fuelwood, either the labor or the product market is assumed to be complete. When only the labor market is incomplete (i.e., a product market exists), a shadow wage can be estimated as the value of the marginal product of labor (Jacoby 1993). For example, Amacher et al. (1999), Köhlin and Parks (2001), and Mekonnen (1999) calculate shadow wages as the value of the marginal product of labor in fuelwood collection. When only the labor market is complete, the reverse approach is possible: the shadow price of fuelwood can be estimated as the value of the time required to collect a unit of fuelwood. For example, Cooke (1998) and Bardhan et al. (2001) use time to collect a kilogram of fuelwood multiplied by the household wage. In a third approach, Pattanayak et al. (forthcoming) and MacDonald et al. (2001) use the cost of a collection trip (wage multiplied by time) in travel cost models of fuelwood collection. Finally, the collection time itself is used in some studies as a proxy biophysical variable, representing scarcity of the forest resource (Edmunds 2002, Heltberg et al. 2000). While the direction of influence varies, almost all studies find that household behavior is significantly influenced by the productivity of labor in fuelwood collection, whether that is interpreted as a factor in the shadow wage, a factor in the shadow price, or a measure of scarcity.[2]

If multiple markets are incomplete, as they are for our two case studies, analysts usually resort to reduced form models. This approach has been applied both to specific NTFPs (e.g., fodder, game, rattan) and to the NTFP category in general, represented either as total gross income from NTFPs or total household time allocated to collection of NTFPs (Godoy 2001, Gunatilake 1998, Wickramasinghe et al. 1996). Household behavior is modeled as a function of socioeconomic and environmental characteristics reflecting preferences, technology, and input endowments, rather than prices. In this case, "none of the original parameters and hence the constraints that they are supposed to identify can be identified. There is no justification for any specific restrictive form for the system" (Sadoulet and de Janvry 1995: 160). In general, linear or log-linear functional forms are used, and models are assessed based on their explanatory power and ability to identify determinants of NTFP collection and consumption.

2.4.2 Determinants of Behavior

In studies of both fuelwood and other NTFPs, household size is one of the most common explanatory variables. The number of people in a household affects both production possibilities (as a measure of available labor) and demand (as a measure of cooking and other consumption needs). Size has been found positively and significantly related to collection time, gross income from NTFPs, and production and consumption quantities. Household size and other demographic variables, such as age, may be included in quadratic form to represent non-linear family life cycles. Size may also be combined with or disaggregated into the gender distribution within a household to better represent the labor endowment. Other sociocultural factors (e.g., education and caste) are also hypothesized to reflect production abilities and preferences regarding NTFPs.

Household assets affect production capabilities and preferences, and many studies include some measure of household wealth, such as landholdings (Edmunds 2002, Amacher et al. 1999) and livestock ownership (Gunatilake 1998, Joshee et al. 2000). The effect of wealth varies across studies, even for the same region and NTFP (compare Amacher et al. 1999 and Edmunds 2002). Some studies use wealth as a proxy for permanent income, while others use expenditures or exogenous income from nonforest sources (often negatively related to NTFP collection). These income variables may also reflect the opportunity cost of household labor. Some studies represent income sources as dummy variables, especially when the accuracy of reported income levels is in doubt. Another household variable often included in fuelwood models is ownership of a substitute fuel technology, such as a kerosene stove. Substitutes generally have the expected negative effect on collection and consumption.

Regional characteristics commonly found in these models include measures of the forest stock, which is generally positively related to NTFP collection time and quantities. Other studies emphasize distance to forest (generally negatively related to collection) and/or distance to market (generally positively related to fuelwood collection, but negatively related to gross NTFP income). Despite these commonalities across models, the specific combination of variables and specific measurement of those variables differs substantially among studies (*cf.* chapter 16).

To summarize, recall that collection (quantities and time allocation) is a function of all exogenous factors, $h(\Phi, \Psi, P, I, H, B)$, in nonseparable household models. In practice, these factors are typically represented by variables drawn from the following categories:

1. Household demographics
2. Wealth or assets (physical and human capital)

3. Income opportunities or sources
4. Substitutes
5. Regional resource and market characteristics.

The choice of specific variables depends on the particular NTFP, the socioeconomic and ecological context, the available data, and the objectives of the analysis. For reduced form estimations of nonseparable models, representation of the variables is governed by hypothesized relationships, data quality, and goodness-of-fit, rather than any theoretical restrictions.

3. CASE STUDIES: INDIA AND BRAZIL

The richness of the household production model as a tool for examining economic behavior in subsistence and low-income economies is illustrated by two case studies. Each study provides insight regarding the interplay between agricultural and forest-based activities in areas where access to markets for labor and production outputs is limited. Policy concerns in both areas arise from the role of NTFP collection activities in the sustainable use of forest resources.

In the first case, we model fuelwood collection (quantity of fuelwood supplied) in the Malnaad region of the Western Ghats of India. These forests have been used heavily for grazing, mulch, fodder, and fuelwood. Forest land tenure falls under two regimes: private access forests (*soppinbettas*) for which usufruct rights are held by particular households, and *de facto* open access forests in which all community members can collect NTFPs. Fuelwood serves as an input to agriculture (processing areca nut and sugarcane) and household services (cooking and bathing).

In the second case, we model the collection of multiple NTFPs (quantity of labor demanded for collection) in the Tapajós region of the Brazilian Amazon. This forest is federally owned and officially designated for timber production, although no large-scale harvesting had taken place at the time of this study. Local households had informal access to the forest under a *de facto* open access tenure regime, effectively regulated only by community norms. The NTFPs collected in this case are both consumed by the households (as food and medicine) and occasionally sold in the market.

Data were collected through surveys of 260 Malnaad households in 1992 and 324 Tapajós households in 1997 (Lele 1993, Pattanayak and Sills 2001). Although the specific questions varied, both surveys provide information on household demographics (family size, age, proportion male), human capital (education, years in local area), and physical assets (land, cattle). Malnaad and Tapajós households are similar in that they both rely on agriculture as their primary economic activity, harvest only small quantities of timber on a

sporadic basis, and have limited opportunities for wage labor.[3] While they collect different NTFPs, both rely primarily on household labor for collection and face significant transactions costs that serve as barriers to market participation.

The case studies demonstrate alternative approaches to two methodological issues. First, there were missing values in both data sets due to household nonresponse to particular questions. For Malnaad, we use class-based imputation to interpolate missing fuelwood quantities, based on median values for households from the same socioeconomic class, in the same village, collecting from the same source. In the Tapajós, we use community averages for several explanatory variables, which then represent community, as opposed to individual household, conditions.

Second, we illustrate two approaches to quantifying household wealth or socioeconomic class: cluster and principal components analyses. These are two of the most common methods for grouping observations by attributes when there is no *a priori* classification scheme (Hand 1981). They incorporate more of the available information than previous studies that have proxied wealth with individual variables such as land or livestock ownership. Malnaad society is distinctly stratified, with wealthier households generally having higher income and more assets of all kinds (Lele 1993). We therefore cluster households using measures of both physical and human capital. In the Tapajós, previous cluster analysis of households (Sills et al. 2000) was found to mask different relationships between specific types of assets and forest use, consistent with the asset specialization among Amazonian households found by Takasaki et al. (2000). We therefore summarize different types of household wealth using principal components.

3.1 Fuelwood Collection in India

In Malnaad, all but a few households collect and consume fuelwood. The largest proportion (47%) collects only from open access forest, while a somewhat smaller proportion collects only from private access forest (42%), and 11% collect from both ownership types. To place this in the context of the household production model developed above, consider first the 58% of households that control private access forests and hence have two supply options. Private access forests are generally more accessible and have better, or at least better known, stocks of fuelwood. Therefore, the marginal cost of collection from private access is likely to be lower than the marginal cost of collection from open access for initial units of fuelwood. However, collection from private forests entails an additional cost, in terms of reduced future fuelwood stocks and thus higher future collection costs ($\partial f_2 / \partial F_1 < 0$). Users of open access forests do not consider this opportunity cost of reduced

fuelwood stocks. Hence, the marginal cost of collection from open access is likely to rise more slowly than the marginal cost of collection from private forests. If household demand is sufficient, collection will eventually switch to open access forest. These relationships are consistent with the greater quantities of fuelwood collected from private access forest (mean = 3993 kg per household per year, st.dev. = 2508) than from open access (mean = 1317, st.dev. = 1913). Of course, for the 42% of households who do not control private access forest, the marginal cost of collecting from open access forest is the only relevant supply curve.

3.1.1 Empirical Specification

To investigate whether there are differences in collection behavior, we specify separate models for open and private access forests (*cf.* Joshee et al. 2000 and Mekonnen 1999). We include all households in the model of collection from open access forests and use a Tobit estimator to account for households that do not exercise this option. Only households with private access forest are included in the second model, which is estimated with OLS. Note that in the Malnaad context, control of private access forest is not a choice but rather an inherited endowment.

Explanatory variables are drawn from the five categories listed in section 2.4.2 (table 15.1). To represent wealth and income, we divide households into three classes through nonhierarchical cluster analysis based on all available measures of physical and human capital.[4] The method initially divides the households into three clusters and then reassigns them to the closest cluster, as defined by Euclidean distance to the cluster median (Johnson and Wichern 1998). This k-medians clustering produces reasonably balanced cluster sizes and classifies households in a manner consistent with field observations on social stratification. As expected, the clusters are quite distinct in terms of both land ownership (e.g., 100% in the wealthiest cluster and 13% in the poorest cluster control access to private forest) and other socioeconomic characteristics (e.g., 34% in the wealthiest cluster and 82% in the poorest cluster have less than a fifth-grade education).

While previous analysis suggested that class variables capture most differences among households (Lele 1993), it is possible that the individual variables used in the cluster analysis could affect household production abilities or preferences independent of their relationship to class. To test the null hypothesis that the class variables capture all of these influences, we include both the cluster variables and their component variables in the estimations.

Table15.1. Characteristics of Malnaad, India (n=255)

Variable	Definition	Mean	St. dev.
HH size	Number of household members	7.00	3.71
% Male	Percent of household who are males of working age	0.37	0.18
% Low educ.	Percent of household with less than 5th-grade education	0.57	0.34
Off-farm job	Dummy = 1 if household has job outside of village	0.08	0.27
Livestock	Number of cattle and buffalo owned	5.45	5.78
Sugarcane	Dummy = 1 if cultivate sugarcane	0.03	0.10
Areca	Dummy = 1 if cultivate areca	0.69	0.46
Private forest	Hectares of private access forest	9.15	8.26
Substitute	Dummy = 1 if own substitute fuel technology	0.35	0.48
Forest access	Accessibility of open access forest, on scale of 1 to 10	4.73	3.12
Road access	Dummy = 1 if better road access	0.67	0.47

3.1.2 Results[5]

Table 15.2 presents estimation results for fuelwood collection from open access and private access forests. The only common result across the two models is that larger households collect more fuelwood. In the case of private access, the square of size is negative and significant, suggesting diminishing marginal productivity of labor due to the fixed area of private forest. In general, there are more statistically significant variables in the open access model, possibly due to the larger number and greater variation of households in that sample. The class variables are significant only in the case of open access: all else equal, poorer households collect the most and middle-class households the second most from open access forest.[6]

The null hypothesis that the component variables have no effect is clearly rejected. Households with little education who are not employed outside the village collect significantly more fuelwood from open access forest. This may reflect their lower opportunity cost of time. The number of cattle and buffalo owned is negatively related to private and positively related to open access fuelwood collection. Households may use cattle to transport fuelwood from the more distant open access forests, and/or they may herd cattle and collect fuelwood at the same time (joint production). If livestock grazing diminishes forest productivity, households may prefer to limit joint grazing and fuelwood collection on private access forest.[7]

Sugarcane and areca cultivation are associated with fuelwood collection from different forest types. The coefficients on sugarcane indicate that jaggery production is a major factor in fuelwood consumption from open access forests. The negative coefficient on this variable in the private forest specification suggests that these families either contract out sugarcane processing or obtain the necessary fuelwood from open access forests, encouraging greater overall reliance on these alternative fuel strategies. The coefficients on areca have the opposite signs, perhaps reflecting the

historical relationship between areca orchards and allocation of private access forest. As expected, acres of private access forest is positively correlated with collection from those forests and negatively correlated with collection from open access forest. Finally, ownership of a substitute has the expected negative effect only on collection from private access forests. Regional variables only affect collection from open access forest: households that have better access to the forest and to the road collect more fuelwood.

Table15.2. Estimates of fuelwood collection in Malnaad, India

Variable	Open Access [a]		Private [b]	
	Coefficient	p-value	Coefficient	p-value
Intercept	-6536.9	0.000	-32.88	0.984
HH size	363.32	0.053	361.50	0.003
HH size^2	-15.08	0.198	-7.70	0.054
% Male	408.61	0.628	1291.77	0.282
Poor class	2486.85	0.019		
Middle class[c]	1239.34	0.143	-389.05	0.504
% Low educ.	1060.44	0.076	-843.62	0.344
Off-farm job	-1283.7	0.108	246.12	0.726
Livestock	103.54	0.015	-82.05	0.048
Sugarcane	4743.79	0.003	-2431.8	0.042
Areca	-2081.6	0.000	1943.18	0.002
Private forest	-92.98	0.103	87.74	0.025
Substitute	6.95	0.986	-1156.9	0.003
Forest access	545.27	0.000	110.49	0.435
Road access	1980.04	0.003	-37.10	0.969
σ	1803.58	0.000		

[a] Tobit model; sample size = 255; log-likelihood = -1104.5.
[b] OLS, corrected for heteroskedasticity; sample size = 151; adjusted R^2 = 0.224.
[c] Definition of this variable differs across the two regressions: for open access forest, it designates the 38% of households (out of 255) in the middle class, while for private access forest, it designates the 60% of households (out of 151) in either the middle or poor class.

3.2 Collection of Multiple NTFPs in Brazil

In the Tapajós region, 84% of households collect NTFPs, including vines, honey, nuts, fruits, and medicinal products. On average, these households reported collecting five products (counting all fruits as one product). In contrast to Malnaad, households in the Tapajós rarely collect fuelwood from the forest but rather rely on dead wood from agricultural fields and fallows. Most households spend less than 10% of their time collecting NTFPs, and only a very few households indicated that forest products are a primary source of income. Nevertheless, NTFP collection is important to these households, as evidenced by community action and

negotiation to defend *de facto* access rights to the Tapajós National Forest. To better understand the role of NTFPs in the livelihoods of these households, we focus on their time allocation, and, specifically, on their derived demand for forest collection trips.

We use the annual number of typical collection trips as an index of labor allocation to NTFP collection largely because it was relatively easy for households to recall. As is often the case with high-value, low-volume NTFP collection from tropical forests, the Tapajós households had difficulty remembering precise quantities and time allocated to collection of specific products. To place our measure of collection effort in the context of the household production model described earlier, consider figure 15.1 relabeled with number of trips on the horizontal axis and cost or return to trips on the vertical axis. The demand (WTP) for trips derives from the household demand for forest products, as both subsistence and commercial goods, while the supply (MC) depends on the effort required per trip and the opportunity cost of household time. Households do not hire others to take forest collection trips, probably due to the difficulties of monitoring effort and the particular human capital (knowledge of forest) required. Therefore, this is another case of household production with missing markets.

3.2.1 Count Data Model

The number of NTFP collection trips in the survey year is a non-negative integer variable, best modeled using the count data approach described in chapter 19. In this case, 31% percent of households report zero trips. Among those who report positive trips, the mean is 8.6, and the standard deviation is 12.4. One explanation for this distribution is that (a) some households are not collectors and make zero trips, and (b) among the collecting households, a few also make zero trips in the survey year, many make a small number of trips, and a few make a large number of trips. Pattanayak and Sills (2001) conclude that the best fit to these data is a zero-inflated-tau negative binomial model. The negative binomial accounts for the overdispersed count of trips (variance greater than mean). The probability of being a collector is modeled as a multiplicative function of the variables explaining the count, with tau as the single additional parameter (Cameron and Trivedi 1998).

With the count of trips as the dependent variable, the independent variables are drawn from the five categories listed in section 2.4.2. As in the Malnaad, household wealth or assets are key explanatory variables, affecting consumption preferences, ability to sell products, and the opportunity cost of collection. To represent wealth in this case, we create linear combinations of different types of household assets, using principal component analysis (see chapter 14).[8] The model includes the first principal component of each set of

variables, which are all correlated in the same direction with the first component because they are selected to represent a like set of assets.

Finally, we return to the observation that even though NTFPs comprise only a small part of income and labor effort, the households claim they are important and have actively sought to protect access to them. Pattanayak and Sills (2001) suggest that this is because NTFP collection serves as a form of natural insurance, providing a backstop source of income to households who have access to the forest and know how, where, and when to find NTFPs. This suggests that forest collection trips provide valuable on-the-job education about the spatial and temporal distribution of NTFPs ($\partial f_2/\partial T_{F1} > 0$) and that households facing greater risks should take more trips. We test this hypothesis by relating trips to two variables representing risk and shortfall at the community level: variability in production of the main agricultural crop (manioc) and percent of households who reported a worse than usual harvest. For details on how these variables are measured and incorporated into the household production framework, see Pattanayak and Sills (2001).

3.2.2 Results

As in the Malnaad case, the estimation results reported in table 15.3 show that household demographics affect NTFP collection patterns: middle-age households with more men make more forest collection trips. Informal education about the local forest, represented by percent of life spent in the local area, is positively related to number of collection trips. The results support our hypothesis that NTFPs serve as natural insurance, since agricultural risk and shortfalls are both positively correlated with collection trips. Contrary to expectations, neither the number of children living outside the forest (potential source of remittance income) nor distance to forest (resource access) is statistically related to collection trips. The former may indicate that the backstop possibilities provided by the immediately available forest and by children who live far from home are not good substitutes. The latter may indicate simply that we have not captured the relevant travel cost variable, which depends on the specific collection site preferred by households and is therefore difficult to measure.

Turning to the principal components of household assets, we see that NTFP collection is positively associated with several measures of wealth, contrary to fuelwood collection from open access forest in the Malnaad and to much of the literature reviewed in section 1.1. For example, trips are positively related to garden production assets (poultry, orchards, gardens) and to domestic assets (clocks, radios, sewing machines). The coefficient on agricultural wealth also has a positive sign, although it is not significant at the 10% level.

Table15.3. Household demand for NTFP collection trips in Tapajós, Brazil

Variable	Definition	Coeff.	p-value	Mean (st. dev.)
Intercept		-3.95	0.000	
Age	Age of head of household in decades	0.74	0.028	4.55 (1.61)
Age^2	Square of age	-0.09	0.006	na
Men	Number of males	0.12	0.101	1.90 (1.34)
Local	Percent of life spent in current village	0.75	0.001	0.72 (0.37)
Children out	Number of children living outside national forest	-0.04	0.282	1.62 (2.33)
Distance	Walking distance to forest	0.02	0.818	1.03 (0.91)
Risk	Coefficient of variation of manioc	14.01	0.000	0.17 (0.02)
Shortfall	Dummy = 1 if poor crop	1.71	0.023	0.17 (0.10)
Principal Components				
Agric. PC	PC of agricultural assets	0.11	0.138	0.22 (1.00)
Livestock PC	PC of ranching assets	-0.29	0.017	0.04 (1.30)
Fishing PC	PC of fishing assets	0.02	0.893	0.97 (0.60)
Garden PC	PC of garden assets	0.29	0.005	1.31 (0.78)
Home PC	PC of domestic assets	0.46	0.006	1.04 (0.53)
Alpha		1.54	0.000	
Tau		-1.55	0.135	

Sample size = 308 Log-likelihood = -803.3 Vuong Statistic = 2.94

This positive correlation with wealth may reflect the fact that these NTFPs are not necessities for day-to-day survival, like fuelwood in the Malnaad, but rather add some variety to consumption possibilities. On the other hand, collection trips are negatively associated with ranching assets, where head of cattle owned has the greatest weight in that principal component. Two possible explanations for the different signs on ranching and other types of wealth are that cattle may represent an alternative way to mitigate risk (i.e., an alternative form of insurance) and that investment in ranching may reflect a more modern orientation and choice of a wealth accumulation pathway that reduces reliance on NTFPs. These different relationships between asset categories and forest collection would be

obscured by either a single principal component or cluster variables based on all assets. Thus, the use of principal components to represent the diversity of household wealth provides a better understanding of how forest dependence varies across household.

4. SUMMARY

Dependence on NTFPs varies across households, even within relatively small geographic areas that are often perceived as homogeneous by policy makers. Understanding this heterogeneity is key for projects that seek to reconcile conservation and development on the forest margin. For example, we find significant effects of household wealth in both Malnaad and the Tapajós, whether represented as socioeconomic classes or asset categories. The direction of these effects, however, differs across forest type (in Malnaad) and asset categories (in the Tapajós). Livestock, which is often used as a proxy for wealth, may play a much more complex role, as a complement to open access fuelwood collection in the Malnaad and as a culturally distinct alternative risk-mitigation strategy in the Tapajós. Rather than seeking general principles of NTFP use, such as "poor households are more forest-dependent," researchers should build models that account for the particular socioeconomic and environmental context, as well as the type of NTFP. Fuelwood in Malnaad is a good example of a relatively high-volume, low-value NTFP, whose collection depends on labor availability and demands for domestic uses and agricultural processing. NTFPs in the Tapajós are collected much less frequently, in smaller volumes, and we find that determinants are related more to the abilities of the household (age and local knowledge) and to risk and shortfalls in the primary agricultural activity.

Since markets are incomplete in both Malnaad and Tapajós, a wide range of household attributes, rather than an exogenous market price, determine household supply and demand behavior. The household production framework provides a structure for specifying and interpreting models in this context. It also helps identify clues to households' dynamic behavior from typical cross-sectional data. For example, we find that the determinants of collection from private and public access forests in Malnaad differ. In particular, ownership of a fuel substitute substantially reduces collection from private access forest, consistent with the premise that private resources are treated with greater care. In the Tapajós, we find that households facing greater agricultural risks take more forest collection trips, possibly because of a desire to maintain NTFP collection as a fallback option. By granting local households access to public forests, the government could facilitate this

natural insurance. Thus, insight into the highly heterogeneous role of NTFPs in rural household economies around the world can be obtained with micro-econometric modeling in the household production framework.

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[1] Households could also augment the forest stock by planting trees on their land. For simplicity, we do not consider household decisions about tree planting in this model. See chapter 16 for further discussion.

[2] The relationship between productivity and labor allocation differs across studies. The Nepalese households modeled by Amacher et al. (1996) respond to higher productivity (interpreted as a higher shadow wage) by supplying more labor, and likewise households in Indonesia and Zimbabwe modeled by Pattanayak et al. (forthcoming) and MacDonald et al. (2001) respond to higher productivity (interpreted as lower cost of collection trips) by taking more trips. On the other hand, the households in Nepal and India modeled by Cooke (1998), Bardhan et al. (2001), Köhlin and Parks (2001), and Heltberg et al. (2000) respond to higher productivity (interpreted as a lower price for fuelwood or higher shadow wage) by supplying less labor. This could be due to differences in data and estimation procedures, different substitution possibilities or market conditions across regions, or a backward-bending aggregate fuelwood labor supply curve.

[3] Only 15% of Malnaad households include someone who worked for wages outside of the home (half of those outside the village), and only 33% of Tapajós households include someone who participated in wage labor for at least one day in the survey year.

[4] The variables are acres of areca, rice paddy, private access grassland, private access forest, coconut, and sugarcane; caste; number of household members with less than fifth-grade education and with high school degree; number of household members who hold off-farm jobs (in and outside their home village); and number of cattle and buffalo owned.

[5] We report probability values for coefficients, allowing readers to apply their own preferred level of significance. We consider the 10% level to indicate statistical significance, while the 15% level suggests the possibility of a statistical relationship.

[6] While it is insignificant in the specification reported in table 15.2, the class variable combining the poor and middle clusters is negative and significant when the component variables are not included. There may not be enough variation in the private forest sample to separate the effect of class from the effects of the component variables in the cluster analysis. A third possible specification would include interaction terms between cluster variables and other independent variables, but specification testing indicated that most of these interaction terms are insignificant.

[7] Another possibility is that better-off households have fewer but higher quality cattle.

[8] These include 25 categories of assets, some measured simply as dummy variables (dummy = 1 if household owns asset), and others as quantities (e.g., head of cattle). To ensure that the quantity variables do not dominate, we first standardize these variables by subtracting the mean and dividing by the standard deviation.