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RURAL ECONOMY

Valuing Fuelwood Resources Using a Site Choice Model of Fuelwood Collection

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Introduction

Wood is the primary source of household energy for many African countries. Fuelwood is used for cooking meals, heating homes (as the season requires), making charcoal, etc.. Much of the existing literature concerning fuelwood is broad in scope and does not provide insights into the microeconomic relationships that have evolved with fuelwood shortages. For instance, Dewees (1989) suggests that painfully little is known about even the role of urban fuelwood markets in the overall fuelwood scarcity situation. Much of the literature that exists seems to be motivated by a concern over the rate of deforestation that is occurring in many parts of the world. Deforestation has implications for the household which is dependent on wood as well ecologically dimensions for the landscape.

In recognition of the importance of fuelwood as a source of energy, planning tools such as energy gap models have been developed. The focus of the energy gap models has been on projecting demand and supply of wood where massive energy deficits are predicted. Leach and Mearns (1988, pp. 5-9) discuss how these gap models consider aggregate current and future energy consumption compared with the aggregate supply of fuelwood (stock of standing fuelwood and future growth). The policy solutions that fall out of this line of reasoning are expressed by Munslow *et al* (1988, p. 11). "*The fuelwood trap, into which governments and donor agencies fall,* ...[in which they] *assume that they have identified an obvious problem and consequently there has to be a simple solution. Unfortunately, this is not the case.*" (italics in original). The problem with these models is that the spatial nature of the problem is ignored. Fuelwood shortages can be very local in nature and thus large scale projects may not address local needs.

Researchers such as Munslow *et al* (1988), Du Toit *et al* (1985), and the FAO (1978, 1991) suggest that deforestation is more closely associated with clearing land for agriculture and the cutting of green wood for the production of charcoal than with the collection of fuelwood by local people. It must be recognized that in some areas, potential fuelwood shortages have been alleviated temporarily by land clearing activities that produce dry wood. Clearing land allows for a short term increase in aggregate agricultural production, but the loss of woody biomass has implications for maintaining soil quality and watershed management. The loss of this biomass has negative implications for longer term agricultural productivity.

The problem of energy use as an economic decision is attracting the attention of applied economists. The standard approach is to extend the agricultural household production model to incorporate domestic fuel decisions. A small group of researchers have adapted this approach to consider problems such as the adoption of improved stoves [Amacher, *et al* (1992)], the choice between agricultural residues and fuelwood for domestic use [Amacher, *et al* (1993)] and the decision to purchase or collect fuelwood [Amacher *et al* (1996)]. Issues surrounding deforestation have been the primary motivation for this literature. Understanding domestic energy choice is important not only for issues of deforestation in the developing world but as researchers and policy makers are

beginning to realize, for the global environment. The prospects of global warming and the potential importance of carbon sequestration suggests that the economics of fuelwood collection needs to be better understood.

This paper follows the same tradition of modeling as the Amacher *et al* papers in that the site choice (where to collect wood) is seen as part of the household resource allocation decision. A micro approach is useful for isolating the nature of the trade-offs occurring in the household production process with respect to fuel choices. For rural areas in north-eastern Zimbabwe, where the data for this study were collected, energy sources such as bottled gas and electricity for domestic use are not available outside urban areas. Since the sale of fuelwood is largely prohibited on communally held land, households must collect their own fuelwood. Here is where the significant difference lies between this paper and Amacher *et al*: the decision to collect wood becomes a becomes a discrete choice problem concerning whether or not to collect wood at a particular site if the sale of wood is prohibited. This requires a very different approach to modeling the fuelwood collection decision. In this case, a travel cost approach embedded in the household production process is used to model the site choice problem. The various attributes of the site as well as the measure of effort to get to each site are likely to be important factors in the site choice. If the opportunity costs of time are not well described by wage rates due to the thinness of the labour market, the next best alternative may be to use a measure of effort such as time, difficulty ratings or an estimate of calorie expenditures. If calories are used in the estimation of the models of choice, then calories provide an alternative means of expressing the welfare losses that the household or community may experience due to closure of the site.

Household Production Models

In developing countries, the rural household is both a producer and consumer of goods and services. The rural household, often headed by women, might grow a cash crop for sale in the market and a staple good for home consumption. The time of adults and older children will be divided between agricultural production, water and fuelwood collection, child-care, cooking meals and the production of crafts, etc.

Modeling the rural household is most easily approached by concentrating on the allocation of time using the basic framework of Becker (1965) and extending it to the salient features of household agricultural production following Singh *et al* (1986). The basic idea is that the household allocates its labour towards the production of goods, some of which are intended for household consumption and some will be sold to generate cash income. A central feature of the simpler household production models is that the production decision is independent of the consumption decision. However, consumption decisions are influenced by production decisions through the sale of surplus goods, referred to as the 'profit effect'.[1] Profits from the sale of surplus agricultural produce or other goods will increase the cash income of the household which then allows the household to purchase more goods. If the

profit effect is an unimportant factor in the consumption decision, then consumption and production can be modelled separately. In many cases, the profit effect can significantly alter the direction and the magnitude of the labour allocation and consumption decisions.

It is generally assumed in the household production literature that households are price takers for all inputs and outputs including labour and that markets exist for all the goods produced. Further, it is assumed commodities are homogeneous, i.e. hired labour is a perfect substitute for household labour. These assumptions are sufficient[2] for the model to be recursive, that is for production and consumption decisions to be treated as if they were sequential with production decisions being made first even though these decisions might be going on simultaneously. In specifying the household production framework below, a number of these assumptions will be relaxed. The result is a fuller and richer framework that can be used to describe the economic situation within which households make choices.

The household ***h*** obtains utility from basic goods and services where some of these goods are produced by the household (*h* superscript) and some are purchased (*p* superscript). The utility function can be written as:

(1) $$U_h = U(X_d^h, X_d^p, X_o^h, X_o^p, X_m, X_l)$$

where X_d is household consumption of food which is made from the agricultural product. Food may be purchased or the agricultural product might be transformed through the labour of the household into food. The agricultural product, X_a, may also be purchased or produced by the household.

X_o is household consumption of all other goods some of which are purchased and some are home-produced,

X_m is household consumption of goods that can only be purchased (often referred to in the literature as marketable goods) and

X_l is household leisure.

The goods are described in terms of household produced versus purchased because of the mark-up between value of the good to the household and the price at which the household, as producer, is able to sell the good. The price differential is due to marketing costs which might include transporting the good to market, economic profit for the marketer, etc..

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[1] The term profit is being used quite loosely in this literature. If all prices are determined through a competitive market then economic profits will be zero.

[2] See Singh *et al* (1986). Note these conditions are of course not necessary. For instance, commodity homogeneity can be relaxed but households must be restricted from corner solutions i.e. consuming all that they produce.

The household has an endowment of household labour time. If labour, as measured by the amount of time spent working on particular tasks, is homogeneous for the purposes of production, then the labour constraint can be written as:

$$(2) \quad L_a^h + L_d^h + L_W^h + L_o^h + X_l = H$$

where household time is allotted to agricultural production L_a^h, , food preparation L_d^h , fuelwood collection L_W^h, , the production of other goods L_o^h , and leisure X_l which must add-up to the total amount of household time *H*. In writing the constraint in this manner, it is implicitly assumed that all labour time is substitutable.

If there is a significant division of labour by gender, i.e. labour resources are not effectively homogeneous, then it is important to account for these difference in the labour allocation decision. There are numerous examples in the literature with studies such as Ahmed (1992), Tinker (1994), Tisch and Paris (1994) which suggest distinct roles for women in the indigenous economy. To account for substitutions in male/female labour, the activities of the household can be further decomposed into labour time by gender with male and female labour time is denoted by *m* and *f* on the household superscript in equation (3).

$$(3) \quad L_a^{h_m} + L_a^{h_f} \; L_d^{h_m} + L_d^{h_f} + L_W^{h_m} + L_W^{h_f} + L_o^{h_m} + L_o^{h_f} + X_l^m + X_l^f = H$$

To allow for a more realistic representation, the labour constraint could be thought about as having a time and effort component. Some tasks, such as preparing the ground for seeding, will require more effort compared with tasks such as cleaning pots or brewing beer. The labour resources devoted to these various tasks must add up to the total human resources of the household.[3]

The household produces an agricultural staple according to well-behaved production function:

$$(4) \quad A = f(L_a, \overline{N})$$

where L_a is the total amount of labour devoted to agriculture. The term L_a includes labour contributed by the household L_a^h and labour (L_a - L_a^h) which is hired. If $L_a < L_a^h$, then the household sells some of its agricultural labour effort. (Total labour effort devoted to home production of food, other goods and to fuelwood collection can be hired or sold in a similar manner.) The fixed variable $\overline{N}$ is the total amount of arable land. The total amount of the agricultural product *A* may exceed household consumption X_a^h in which case the surplus could be sold to generate cash. If $A < X_a^h$ then the household purchases X_a^p to be used in the preparation of food.

[3] The gender superscripts will not be carried throughout the equations but remain implied. Demand equations for male and female labour will be specified later in this proposal. Note it is assumed throughout the analysis that there is only one competitive wage p_L. An interesting extension would be to allow for wage differentials by task which would likely have some gender implications.

The household uses fuelwood as a source of energy for heating and in preparing household meals. There would seem to be two important characteristics of the wood; whether it is wet or dry.[4] However, if the wood from different trees and shrubs have different characteristics or desirable properties, i.e. intensity and duration of how the material burns, then the analysis can be expanded to allow for species differentiation. The amount of dry or wet fuelwood collected by the household will depend on the total amount of labour effort L_W and the stock of wood S_j:

(5) $$W_j = f(L_W, \overline{S}_j) \quad for\ j = wet\ or\ dry$$

The household can choose to collect only the household's requirements, W^h, a surplus $W > W^h$ or choose a deficit level and purchase the rest.

The household prepares food according to the following well behaved production function:

(6) $$D = f(X_a^h, X_a^p, L_d, F_j, W^h)$$

The household uses the agricultural staple and the variable inputs labour, fuel F_j [5] (paraffin) or W^h in the production of heating and cooked food. If $D = X_d^h$, then prepared food is neither bought nor sold by the household. The production of food and other goods is likely to be at levels required by the household but this flexible model formulation will allow for the sale and purchase of goods and services.

The household produces an assortment of other goods and services such as child-care, water collection, etc. using the variable factor labour L_O.

(7) $$O = f(L_o)$$

The overall budget constraint ensures that all purchases add up to all cash earnings, plus any exogenous income. There are a few sources of cash income including: selling the surplus agricultural staple, selling surplus fuelwood, selling home-produced other goods or selling labour and through receiving remittances from extended family. In developing countries, remittances, included in E for exogenous income, can represent a significant source of income for rural households. Further, aid, whether in the form of food or in cash, can also represent an important source of exogenous income.

On the consumption side, the budget constraint is:

(8) $$Y = p_a^s X_a^h + p_a^p X_a^p + p_d^s X_d^h + p_d^p X_d^p + p_m X_m + p_o^s X_o^h + p_o^p X_o^p + p_L X_L$$

where

[4] The subscript denoting type of wood will be suppressed for the sake of brevity.
[5] The subscript denoting type of fuel source will be also be suppressed after equation (6).

p_i^s is the price at which the household is able to sell of good *i* i.e. the agricultural good or the other good,

X_i^h is the amount of good *i* produced by the household that is actually consumed by the household,

p_i^p is the price that the household is able to purchase the agricultural good,

X_i^p is the amount of the good *i* that is purchased by the household

p_m is the price of the marketable good and

On the production side, the household's full income would be:

$$Y = p_L H + (p_a^s A + p_d^s D + p_W^s W + p_o^s O) - (p_L (L_a - L_a^h) + p_L (L_d - L_d^h) + p_L (L_W - L_W^h) + p_L (L_o - L_o^h) + p_W^p W^h + p_f F) + E \quad (9)$$

where p_W^p is the price at which the household can purchase fuelwood, p_f is the price of other fuel[6] and E is exogenous income. Substituting (8) into (9) and re-arranging yields:

$$p_m X_m + p_L X_l = p_L H + p_a^s (A - X_a^h) - p_a^p X_a^p + p_d^s (D - X_d^h) - p_d^p X_d^p + p_W^s (W - W^h) - p_W^p W^p - p_f F + p_o^s (O - X_o^h) - p_o^p X_o^p - p_L (L_a - L_a^h) - p_L (L_d - L_d^h) - p_L (L_W - L_W^h) - p_L (L_o - L_o^h) + E \quad (10)$$

The value of leisure has been included in the budget constraint because the household foregoes the market wage when a household member engages in leisure. The household may hire additional labour or sell its labour effort for agricultural production, fuelwood production or home-produced other goods. For example, if $L_O \geq L_o^h$ then the household will hire labour to assist in the home production of goods such as child care.

The household produces *D*, *O* using the agricultural output, labour and fuel, the variable inputs, and the fixed factors *N* and *S*. The intermediate goods, outputs and inputs of household production can be summarized through the implicit production function *G*.

[6] The difference between the price the household is able to sell and the price the agricultural product, food, fuelwood or other goods and services can be purchased at is due to transportation costs, mark-up by merchants, risk premiums, etc. If the household's shadow price falls in between the selling and purchasing price, trades will not occur. The market will be thin or non-existent.

$$(11)\quad G(A, D, F, O, L_a, L_d, L_w, L_o, F, W^h, \overline{N}, \overline{S}) = 0$$

The implicit production function is assumed to be quasi-convex, increasing in outputs D and O and decreasing in L_a, L_d, L_W, L_O, F and W^h.

The constrained optimization problem as the household allocates labour resources as follows:

$$(12)\quad \begin{aligned} &Maximize \quad \Psi = \mathrm{U}(\mathrm{X}_{a,} X_{m,} X_o, X_l) + l \quad (p_L H - p_m X_m + p_a^s (A - X_a^h) - \\ &p_a^p X_a^p + p_d^s (D - X_d^h) - p_d^p X_d^p + p_W^s (W - W^h) - p_W^p W^p - p_f F + p_o^s (O - X_o^h) \\ &- p_o^p X_o^p - p_L (L_a - L_a^h) - p_L (L_d - L_d^h) - p_L (L_W - L_W^h) - p_L (L_o - L_o^h) - p_L X_l \\ &+ E) + m\, G(A, O, L_a, L_W, L_o, F, W^h, \overline{N}, \overline{S}) \end{aligned}$$

The First Order Conditions

The first order conditions suggest that the household will maximize its utility and the profitability of its production activities if :

- ☞ it sets the ratio of marginal utilities for each pair of consumption goods equal to the ratio of the market price of the goods,
- ☞ it stays within its budget constraint and operates on its production frontier,
- ☞ it produces the optimal combination of goods, and
- ☞ it allocates variable factors, labour, purchased fuels and fuelwood, efficiently amongst potential uses.

$$(13)\quad \begin{aligned} &U_{X_a^h} - l\ p_a^s = 0 \ or\ U_{X_a^h} = l\ p_a^s \qquad U_{X_a^p} = l\ p_a^p \qquad U_{X_o^h} = l\ p_o^s \\ &U_{X_o^p} = l\ p_o^p \quad U_{X_m} = l\ p_m \qquad U_{X_l} = l\ p_L \end{aligned}$$

$$(14)\quad \begin{aligned} &p_L H + p_a^s (A - X_a^h) - p_a^p X_a^p + p_d^s (D - X_d^h) - p_d^p X_d^p + p_W^s (W - W^h) \\ &- p_W^p W^p - p_f F + p_o^s (O - X_o^h) - p_o^p X_o^p - p_L (L_a - L_a^h) - \\ &p_L (L_d - L_d^h) - p_L (L_W - L_W^h) - p_L (L_o - L_o^h) - p_m X_m - p_L X_l + E = 0 \end{aligned}$$

$$(15)\quad G(A, O, L_a, L_W, L_o, F, W^h, \overline{N}, \overline{S}) = 0$$

$$
(16)\quad
\begin{aligned}
&l\ \ p_a^s\, A_{La} - p_L + m\ \ G_{La} = 0\\
&l\ \ p_d^s\, A_{Ld} - p_L + m\ \ G_{Ld} = 0\\
&l\ \ p_W^s\, W_{L_W} - p_L + m\ \ G_{LW} = 0\\
&l\ \ p_o^s\, A_{Lo} - p_L + m\ \ G_{Lo} = 0\\
&l\ \ p_f\, D_f - p_f + m\, G_f = 0\\
&l\ \ p_w^s + l\ p_d^s\, D_{W^h} + m\ \ G_{Ld} = 0
\end{aligned}
$$

Without making assumptions about the functional form of the utility function and the production function, it is not possible to solve explicitly for the demand for inputs (labour, fuel and fuelwood) or the demand for home consumption of produced and purchased goods. The demand functions in general form will be:

$$
(17)\quad X_a^h = f\left(p_a^s,\, p_a^p,\, p_d^s,\, p_d^p,\, p_m,\, p_o^s,\, p_o^p,\, p_W^s,\, p_W^p,\, p_L,\, p_F,\, E\right)
$$

The household demand functions suggest that the demand for these goods will depend on its own price, the price of other goods, the price of inputs into the production process and exogenous income. The demand for inputs into the production process will similarly depend on the price of inputs and the price of outputs. For instance, the demand for fuelwood collected by the household will depend on the purchase price for fuelwood, the price of other fuels, the price of other goods and the wage paid to labour. The household production model establishes a theoretical framework for analyzing the trade-offs that the household makes in terms of its resources.

The market for any one of the inputs to the household production process may be thin or non-existent for any number of reasons. In the case of fuelwood, where the resource is often located on communally held land, property rights may be such that the sale of fuelwood is prohibited and strictly enforced through social institutions. In other cases, the marginal rate of substitution between purchased fuelwood and other purchased goods may exceed the price ratio resulting in a corner solution where no fuelwood is purchased. In the rural sector, the majority of households may be at a corner solution and the market for fuelwood would be thin. The household, constrained to the collection of fuelwood must then consider the problem of where to collect fuelwood. These choices still involve time and effort levels by members of the household.

A further complication arising from the household production model is that fuelwood may be collected at a number of sites and individuals face different costs, and experience different benefits, from choosing these sites. Thus, while fuelwood markets may be limited by regulation, real opportunity costs of collecting fuelwood from different sites are felt by individual households. These costs are often not experienced in monetary terms but become part of the resource outlays by the households. Below we turn to a discussion of the selection of fuelwood collection sites and the costs faced by household members as modelled in a random utility framework.

Applying Discrete Choice Theory to Fuelwood Collection

A body of literature has developed in the transportation, marketing and recreation literature concerning discrete choice situations where the individual (or the household) makes a decision - yes or no - to take the bus to work or not, to purchase a good or not, etc. The decision to collect fuelwood at a particular collection site fits in the general framework. First, let us consider the random utility model and then the investigate how useful it might be for explaining site choice in fuelwood collection.

The Random Utility Model

The choice of where to collect fuel could be modelled in the random utility model (RUM) framework (see Ben Akiva and Lerman). To illustrate, let us take the example of a fuelwood collector, a rational individual, who chooses a forested site *i* from his/her choice set C_h with probability equal to the probability that the utility associated with choice *i* is at least greater than or equal to the level of utility to be achieved with any of the other *j* alternatives in the choice set.

(18) $$P(\, i \mid C_h\,) = \Pr(U_{ih} \geq U_{jh}) \qquad \forall\ j \in C_h$$

However, utility is not directly observed. Levels of indirect utility, denoted V(.), can be inferred by the choices observed with some random error. The utility from choice *i* of household *h* can be rewritten as:

(19) $$U_{ih} = V(p,\, a_{ih},\, s_h\,) + e\,(a_{ih},\, s_h\,)$$

where p is the vector of relevant fuelwood "prices" (from equation 17 of the household production model), a_{ih} is the vector of attributes for alternative *i* influencing choice of the fuelwood collector *h*, s_h are the socio-economic characteristics of the fuelwood collectors household and e is the random component. Note that fuelwood prices in this case are not market prices but rather opportunity costs felt by the household of selecting different sites. These costs could be expressed in monetary terms if opportunity costs of time were well known. However, we discuss other approaches to estimating the opportunity costs to the household below. Substituting (18) into (19) and rewriting leads to:

(20) $$P(i \mid C_h) = \Pr\,(V_{ih} + e_{ih}) \ \geq\ \Pr\,(V_{jh} + e_{jh})$$

which means that the individual will collect at site *i* if the indirect utility from site *i* (plus some error) is greater than the utility from site *j* (plus some error).

If the error terms are distributed identically and independently as a Type I extreme value distribution, then the probability of collecting fuelwood at a site *i* is (Ben Akiva and Lerman):

$$\textbf{(21)} \quad \Pr(i) = \frac{e^{V_i}}{\sum_{j=1}^{n} e^{V_j}}$$

where the denominator of (21) is the summation of the exponential of the indirect utility that could have been obtained from the *j* alternative sites. In order to identify the tradeoffs that individuals make when selecting fuelwood collection sites, and the true economic impact of changes in these sites, data on opportunity costs, site attributes and related household factors need to be collected and incorporated into this model.

Description of the Study Sites and the Collection of Data

The fuelwood collection survey was designed as part of a consultation process with local people in the villages. The primary purpose of the meetings was to become familiar with the local economy including the major agricultural crops and major activities of men and women. It was discovered through discussions that women were primarily responsible for wood collection activities. Women will tend to walk alone or in small groups to collect wood from the mountains and hills in the area. Sometimes men will engage in fuelwood collection but men will tend to employ a cart and oxen to carry a large load of wood back to the homestead. Results of a series of village meetings in the Mutoko area of Zimbabwe are reported in Hatton MacDonald and Weber (1998).

A household survey was conducted over a three month period of July through September, 1996 in the Mutoko and Murewa Communal Areas in Zimbabwe. The surveys are specific to the research sites in terms of the names of collection sites but the body of questions are the same for all three study sites. In the Mutoko Communal Area, the two study sites lie in adjacent valleys connected by roads and paths between mountains and hills. These mountains and hills are relatively well forested. The choice sets for households in the two study sites contain a few of the same mountains but usually only one side of the hill or mountain will be accessible to households in a particular study site. These two study sites will be referred to as Nyamakope and Katiyo.[7] In the Murewa Communal Area, a large village, Dandara, was selected for the study. The stock of woodlands have been severely depleted in the immediate vicinity of Murewa study site and as a result people have to travel further to collect wood.

The sites have comparable features in terms of all being Miombo woodlands that have been cleared for agricultural use. These villages were organized on a grid system and each homestead is allocated a field for growing maize and if available, garden space near a source of water. Cattle are grazed in collective held fields, often near the base of the surrounding mountains and hills. The people in these areas generally tend to collect fuelwood in elevated areas as the immediate area near the homestead is cleared of most trees and shrubs.

Four research assistants visited the randomly selected households and queried households concerning site attributes, fuelwood collection trips and socio-economic information about the household on three separate occasions. With each weekly visit, the household[8] was asked to recall over the previous seven days how many trips to collect wood had taken place, how long the trip took and the mode of transportation involved. To avoid respondent fatigue, questions about site attributes and socio-economic status were spread across the first and third visits.

Site Attribute Information

Three species of trees (*Brachystegia glaucescens, Julbernardia globiflora, Brachstegia boehmii*) (or in the local dialects muunze, munhondo, mupfuti) were identified as excellent fuelwood for domestic use. Households were asked to rate how plentiful these species, were on each collection site. Since other species are also used as fuelwood, though not as preferred, respondents were asked to rate how plentiful other fuelwood species are at these sites. To summarize the information in the data, effects codes[9] were set up following Louviere (1988). Table 1 lists the effects codes for the species Muunze. The attribute "plentiful", coded -1, is the benchmark for comparison.

Table 1

Effects Codes for Muunze

How plentiful is muunze?	Muunze1	Muunze2	Muunze3
exhausted	1	0	0
sparse	0	1	0
Moderate	0	0	1
Plentiful	-1	-1	-1

Information was also collected from respondents regarding the difficulty of walking to each of the collection sites. Effects codes were set up to reflect the perceived difficulty for each trip (Table 2).

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[7] The sites were chosen in order to obtain a large enough sample to have sufficient degrees of freedom to estimate a model of choice.

[8] Often there would be a collaborative effort in responding to the questions with several individuals, even neighbours being present for the interview. The research assistants had been cautioned in training to ensure that the women responsible for wood collection were present and that male voices did not dominate the discussion.

Table 2

Effects Codes for Difficulty

Difficulty of the Trip (level)	Difficulty1	Difficulty2
Easy	1	0
Moderate	0	1
Difficult	-1	-1

Through group discussions with women, a number of additional factors which would make the trip to collect fuelwood more pleasant were identified. These included whether there were wild fruits available along the way, whether useful plants or barks could be found along the way, whether the trip passed by the garden, whether the trip passed by a friend's home, whether there were sources of water for drinking, whether wild animals could be found along the way and whether there were good places to rest. A series of dummy variables were assembled to represent these attributes. Finally, households were asked to estimate how long, in minutes, it would take to reach each collection site.

The dataset was completed by collecting information on the distance from the household compound to the base of the mountain or hill using detailed topographical maps. Calorie expenditures were calculated using the perceived difficulty rating and the estimated time spent walking to calculate an estimate of calorie expenditure for each household to each site.[10]

Estimation Results

In the case of a fuelwood collection trip, the attributes of the sites and of the trip, as well as measures of the travel cost, whether in terms of calories, time or distance should be a factor in site choice. For rural households, time is a valuable input in the household production process and presumably time not spent collecting wood could be used for other economic activities or in leisure activities. The availability of different types of fuelwood and the other site attributes such as wild fruits, barks, friends, water, wild animals and places to rest may also enter the choice process. The decision to take a trip to site *i* can be modelled as follows:

Trip to site i = f{ travels costs (as measured by distance, time or calories),

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[9] Effects codes translate category-rating scales to a coding system based on statistical design principles.

[10] Caloric expenditures for various effort levels were based on the Calorie Calculator, see http://primusweb.com/fitnesspartner, October 4, 1997. Calorie expenditures were cross-checked using tables on p.98 and p.356 of Katch and McArdle (1979). Models of caloric expenditure are generally based on a North American model and some minor adjustment (up or down) may be required to more accurately reflect metabolic differences, altitudes and climate. Overall the estimates of welfare effects (found later in this chapter) will not be affected to any large extent.

availability of the species good for firewood (effects codes for muunze, mupfuti, munhondo and other fuelwood species) and
other site attributes}

Estimation results for the study sites together and the study sites considered separately are summarized in Table 3. There a number of ways that travel costs might be expressed. Time and perceived difficulty are based on the perceptions of the respondents. McLeod (1995) reported that hunters' perceptions of site attributes were often more important variables than the "objective" measures of the site attributes collected by researchers. In this case, both the independently gathered information on distance and perceived travel costs[11] were significant explanatory variables. Travel cost, measured in terms of distance or calories, was a very important variable for the study sites pooled together and two of the three study sites when sites are considered separately. Calories being insignificant in the choice of site in the Dandara site is certainly an unexpected result. Households in Dandara have to walk long distances or take a cart to get to the few sites[12] which are not severely depleted. Travel costs being insignificant suggests that the fuelwood situation is more complicated than might first appear.

Table 3

Estimation Results

Variable	Coefficient	T statistic (Asymptotic)
Model 1: All Study Sites		
Time	-0.0017	-2.588
Difficulty1	1.7599	25.903
Difficulty2	0.2000	2.545
Muunze1	-1.0638	-6.669
Muunze2	0.13562	1.425
Muunze3	0.1597	1.581
Model 2 - All Study Sites		
Calories	-0.0015	-10.733
Muunze1	-1.1634	-7.917
Muunze2	0.0160	0.184
Muunze3	0.3406	3.732
Friends	0.8950	7.483
Rest	1.3408	10.923
Model 3 - Nyamakope		
Calories	-0.0067	-8.961

[11] Perceptions of travel costs by local residents were probably more accurate than the researcher's measurement of distance. Local residents utilise all the foot-paths that were not always visible on maps. Gathering information on the distance form the homestead to the base of a mountain was more of a precautionary step in case there were problems with the surveys questions on time since few people seemed to won a watch.

[12] Taking a cart does not mean there will not be significant calorie expenditures as it is necessary for the collector to walk beside the cart.

Muunze1	-0.5820	-0.832
Muunze2	-0.2105	-0.644
Muunze3	-0.13562	-0.455
Friends	0.9951	4.865
Rest	1.3662	5.708
Model 4 - Katiyo		
Calories	-0.0161	-10.918
Muunze1	-0.9047	-2.679
Muunze2	-0.2478	-1.221
Muunze3	0.5949	3.553
Friends	0.3731	1.670
Rest	0.6664	3.510
Model 5 - Dandara		
Calories	-0.00005	-0.393
Muunze1	-0.89906	-4.429
Muunze2	0.23635	1.557
Muunze3	0.21869	1.238
Friends	0.58914	2.583
Rest	-0.10387	-0.459

The choice process in Dandara may be complicated in comparison to the well-wooded sites in the Mutoko Communal area. For instance, some households are beginning to switch to alternative fuels such as paraffin and solar power. Alternatively, the decision of where to collect wood may be predetermined if the uses (or the hires) a scotch-cart. Access to some sites may be more difficult for a cart than a person walking. As well, the calorie costs will be largely irrelevant for the household that hires a cart and driver. The role of carts in the Dandara site will be investigated in future research with this dataset.

One might expect that limited availability of good quality firewood such as muunze is a deterrent to households at a particular site in the Dandara study area. This expectation is supported by the empirical results where the effects code on limited availability of muunze was negative and highly significant. This suggests that afforestation efforts in the area would be very beneficial to households. To date many of the afforestation efforts have concentrated on introducing fruit trees such as mango or fast growing, non-indigenous species such as eucalyptus.

Other site attributes such as the trip going past the homes of friends would usually be thought to have a positive effect on choosing a particular site. The estimated coefficient on the variable friend was positive and significant for most of the models. Similarly, having a place to rest along the trip was also considered a benefit in the Nyamakope and Katiyo sites, though not in Dandara where the estimated coefficient on the variable rest was negative though insignificant. Factors such as the journey taking the individual by their garden or the presence of wild animals were not very important and for this reason, these variables were dropped from the logistic regression and only the final set of selected variables were reported.

A number of specifications of the model were examined. The models would seem to be quite robust in the sense that the estimated coefficients did not change significantly and certainly did not change signs when other variables were included or excluded. Final models were selected for presentation based on identifying the significant variables common across study sites. Not all insignificant variables were dropped from the models in that the differences across study sites could be highlighted.

Welfare Measures

Welfare measures in economic theory place a value on a change in quantity, quality or price of the good. Small and Rosen (1981) report that the compensating variation for a discrete choice model of the form described above can be calculated as follows:

$$(22) \quad Compensating \quad Variation = \frac{1}{m}\left[\left(\ln \sum_{i=1}^{N} e^{V_{io}}\right) - \left(\ln \sum_{i=1}^{N} e^{V_{i1}}\right)\right]$$

where m is the marginal utility of income,

N is the number of sites,

V_{i0} is the indirect utility for site i before a price (or quality) change and

V_{i1} is the indirect utility for site i after the price (or quality) change.

To simplify the welfare calculations, it is generally assumed that the marginal utility of income is constant.

$$(23) \quad V_i = b\,(Y - TC_i) + a\,Q$$

where V_i is the indirect utility associated with site i,

Y is the household's income,

TC_i is the travel cost incurred in terms to get to the site i, and

Q is a vector of quality attributes.

The marginal utility of income in equation (22) is:

$$(24) \quad \frac{\P V_i}{\P Y} = b = m$$

In the household production framework, the travel cost TC_i in equation (23) might be thought of as time multiplied by the rural wage or fraction of the rural wage. However, the market for labour in rural Zimbabwe is thin so the rural wage may be a poor indicator of the value of time. Alternatively, we may wish to think of the household having a total caloric budget that can be allocated towards the activities the household that result in goods that

yield household utility. In this case, the indirect household utility function, which is a function of the caloric cost of activities (everything other than fuelwood collection being suppressed), will be:

$$V_i = f\,(C - c_i\,,\ Q)$$

where V_i is the indirect utility associated with site i,

C is the household caloric budget,

c_i is the calories required to get to the site i, and

Q is a vector of quality attributes

The marginal utility of calories will be the term B.

$$dV_i = B\,dC$$

Welfare measures in caloric terms can be calculated using the estimated parameters in Table 3. In each of the study areas, the welfare effects were simulated by closing one site at a time and removing it from the choice set. This is a realistic policy simulation since access to sites is becoming an issue in these areas due to granite mining (Katiyo study site), property right disputes (Dandara study site) and ecological concerns.

Removing collection sites may result in households having to travel further to collect wood. Tables 4, 5 and 6 presents the average cost per trip in caloric terms for each community. However, there can be considerable variation within the community. For many households, closing a particular site will have negligible caloric costs but for other households, site closure may have large welfare implications. To illustrate the variation in welfare implications the largest losses as well as the average welfare effects are presented.

Table 4

Welfare Measures for Nyamakope Study Site, Mutoko Communal Area

(calories per trip)

Site	Average Welfare Loss	Largest Welfare Loss
Gonye Mountain	4.58	61.50
Mashayamvura Mountain	3.48	44.72
Ndigamarombe Mountain	17.34	47.03
Vhumbika Mountain	24.94	165.20
Nyatsanza Mountain	5.98	15.81
Chidziro Mountain	10.73	50.08
Karunzviru Mountain	3.34	25.35
Chidzanya Hill	2.28	4.75
Mukangiranyemba Mountain	7.2	29.29
Hova Hill	5.21	63.40
Umba Mountain	13.26	56.70
Suswe Mountain	13.29	55.25
Ruchera Area	2.2	57.34
Marirangwe Mountain	28.77	172.98
Mudenyika Hill	13.55	105.09
Hova Area	1.25	208.77

Table 5

Welfare Measure for Katiyo Study Site, Mutoko Study

(calories per trip)

Site	Average Welfare Loss	Largest Welfare Loss
Tawani Mountain	10.22	65.63
Chijakata Mountain	4.67	38.19
Chindinye Tsvimbo Hill	1.80	12.97
Garireremakoso Mountain	8.78	42.42
Mashayamvura Mountain	6.19	37.24
Mbudziyatume Mountain	2.69	18.71
Rukwiza Mountain	9.74	70.50
Chipangare Mountain	1.23	20.42
Marirangwe Mountain	21.62	107.34
Chidziro Mountain	4.69	37.76
Chitupwana Mountain	8.69	118.44
Gonye Mountain	2.56	36.46

Table 6

Welfare measures for Dandara Study site, Murewa Communal Area

(calories per trip)

Site	Average Welfare Loss	Largest Welfare Loss
Mapunga Mountain	42.2	129.1
Chikwirandaombera Mountain	111.2	226.3
Chamapere Mountain	143.8	225.7
Ndemera Mountain	71.5	128.5
Mucheunje Mountain	74.3	146.0
Muchinijike Mountain	74.1	147.0
Mutaragume Mountain	66.7	117.3
Gugwa Mountain	63.2	103.9
Mazimi Mountain	67.6	116.7
Njedza Mountain	67.3	116.1
Runyange Mountain	65.9	115.2
Kapuka Mountain	63.6	146.5
Masaka Area	71.5	121.0
Bhidi Area	36.6	113.2
Chirozva Area	35.8	113.2
Gova Area	37.9	113.9
Chebhero Area	44.1	109.3
Butuku	44.3	114.4

In general, the distances for each fuelwood collection trip were much greater in the Dandara study site and thus the average losses per trip observed in Table 6 are considerably larger compared with Tables 4 and 5. Further, the maximum values in all three tables indicate that the potential welfare loss can be quite large for individual households. While the results in Table 6 look quite reasonable given the relatively longer distances that people must travel in the Dandara site, it is important to not place undue emphasis on the welfare estimates for this site due to the low t statistic on the calories variables.

Even if we restrict our attention to Tables 4 and 5, the welfare losses associated with closing a site can be quite large. Closing a mountain such as Vhumbika or the Hova Area in Nyamakope would suggest that an increased level of effort of 165 to 200 calories a trip. If the average daily consumption of a Zimbabwean woman is 2000 calories a day, closing a site may well represent ten percent of her daily intake. Given that women are often observed to be the last to eat from the pot, it is unlikely that their intake of calories will be increased to accommodate their increase in effort.[13]

[13] See Dasgupta (1993) for an extensive listing of studies which document the allocation rules used by households concerning access to food and resources of the household. Sen (1981) summarises the controversy concerning caloric expenditures and changes in metabolism. While it is possible that metabolic changes or decreases in other

Summary and Conclusions

A number of researchers have examined the value of non-market goods and services in developing country contexts using contingent valuation methods. In this study we examine behaviour related to fuelwood collection to assess the tradeoffs implicit in the choice of fuelwood collection site and develop a model that can be used to assess the impact of changes in the quality and quantity of fuelwood collection sites. We also examine the use of calories as a measure of the opportunity cost of collecting fuelwood. This provide us the opportunity to value the services with a metric that is relevant to the local community and it provides for the ability to convert this measure into monetary terms by making assumptions on the monetary value of calories.

The results of this study suggest that standard economic models of choice can be adapted to model the decision making processes of the subsistence agricultural household. The empirical results suggest that calories (reflecting distance and difficulty of the journey), attributes of the site such as the availability of good quality fuelwood are important factors in the choice of sites in the Mutoko Communal Area. However, more work remains to explain satisfactorily the choice behaviour in the Dandara study site in the Murewa Communal area.

There are some significant differences between the Communal Areas. As noted previously, households tend to make fewer trips to collect firewood in the Dandara study site. This may be due to a number of different strategies being employed by these households such as conserving fuelwood, using alternative fuels, or using carts to collect wood. The latter strategies involve substituting other fuels for wood or using a labour saving capital good to collect fuelwood. If this is in fact the case, there may be some potential for using nested models of choice to explain the choice between walking and taking a cart and the choice of fuels.

The welfare simulations reinforce the importance of the spatial context of fuelwood shortages. Closing sites may have a relatively small effect on the community but a large effect on the well-being of particular households. For example, the household collecting wood two or three times a week at Chitupwana Mountain in the Katiyo study site, the closure of this site would cost one household 118 calories per trip. When households in this area are making two to three trips a week, caloric expenditures on a day to day basis are of fundamental importance.

The welfare effects have broad policy implications that warrant discussion. For governments considering site closure to protect forested areas, the increased caloric expenditures by women will be a significant but less visible cost for the local population. A government or non-governmental agency which is mindful of these welfare implications has a few options available to redress the situation. For instance, compensation might be provided

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activities may allow a woman to increase fuelwood collection effort for a period of time, over the long term there

through deliveries of staple commodities (or cash equivalents) to increase caloric consumption though customary allocation of food within the household within the household may not result in those most affected by the site closure receiving the food unless careful targeting of the food delivery occurs. Alternatively, afforestation programs may be effective over the long term to improve firewood availability.

The estimation results and the welfare effects may also be of interest to governments from the industrialized world. With recent attention to global warming, governments and industries are interested in the potential for carbon sequestration in the developing world. This research suggests the nature of the costs that would be borne by the local population if stocks of carbon in the form of forested areas were set aside for protection.

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will be significant health consequences.

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