4-1-2010

What is the Impact of Income on the Demand for Bushmeat?: a study of the relationship between income and bushmeat near the Serengeti National Park in Tanzania

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Honors Project

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Spring 2010

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Abstract

In Sub-Saharan Africa, increasing levels of bushmeat consumption and unsustainable levels of bushmeat hunting have become one of the central concerns of conservationists. Many conservationists have recently begun to see income growth as a possible strategy to decrease wildlife consumption. This study tests whether or not this strategy would be effective near the Serengeti National Park in Tanzania. Results from both the aggregated and disaggregated demand functions indicate that bushmeat is a necessity in the region, implying that increases in income would lead to less than proportional increases in consumption and suggesting that income growth alone is not a viable conservation strategy. Other food sources in addition to economic activities that could provide both protein and income must be made available in order to reduce the demand for bushmeat.

Acknowledgements

I would like to sincerely thank my advisor Professor Amy Damon for her guidance, insightful feedback, and constructive criticism. Her encouragement and positive attitude kept me motivated throughout the difficult process. I would also like to thank Professor Raymond Robertson for his feedback at the beginning stages of this project and for the Honors Seminar, without which I could not imagine completing this project. I would like to acknowledge and thank Dennis Rentsch from the Frankfurt Zoological Society for giving me the unique opportunity to work with the data and for his input throughout the process. I would also like to thank my committee members Professors Sarah West and William Moseley for their helpful comments and for giving me new perspectives on certain elements of the project. Finally, I would like to thank my friends and fellow Honors students, who had to endure a whole year of conversations about bushmeat, for their constant support, help, and motivation.

I. Introduction

In Sub-Saharan Africa, many people consume wild animals as food. Bushmeat hunting, or the illegal hunting of wildlife, is considered to be a significant threat to the conservation of wildlife species and wildlife diversity. Unsustainable patterns of bushmeat hunting have been documented (Arnold and Perez, 1998; Murray, 2003; Bennett et al., 2007) and since the 1990s have gained particular attention from governments and conservation agencies. As a response to the growing issue of poaching, in 1989 the Tanzanian government introduced an anti-poaching program "Operation Uhai" that lasted until March 1991 (Songorwa, 1999). It was successful in decreasing poaching at first, but with low levels of financing the *fences-and-fines*[1] strategy was unsustainable in the long-run (Barnett, 2000). This top-down approach oftentimes resulted in the seizure of land from local inhabitants without adequate compensation and was thus coined by many as "conservation against the people" (Baldus and Siege, 2001).

International organizations working in the region proposed an alternative community-based conservation strategy. Since the mid-1990s, programs employing community-based conservation have been seen as an important step in eradicating hunting for wildlife. Several national laws, such as Tanzania's Wildlife Conservation Policy in 1998, supported this community-based approach (Goldman, 2003). By offsetting zones and calling them Natural Reserves or Parks, restrictions and penalties for illegal hunting were put in place. These have not been effective at reducing poaching,

[1] The term *fences-and-fines* refers to the establishment of protected areas with strictly enforced boundaries. No consumptive use of wildlife species within the boundary is permitted. This approach assumes no linkage between livelihoods and conservation and has been the basis of many historical and traditional conservation projects (Brown, 2002)

largely due to inadequate enforcement resources, which cause the potential benefits of bushmeat to outweigh the costs of illegal hunting (Loibooki et al., 2002).

Given the need to find alternative conservation strategies, some have suggested targeting the link between poverty and natural resource dependence.[2] Studies measuring the association between income and wildlife, however, have produced mixed results. The hypothesis that income growth can reduce pressure on wildlife requires empirical scrutiny and depends on whether wildlife is a superior, inferior, or normal good according to its income elasticity. If wildlife is a superior good ($\varepsilon_I > 1$), then increasing income would generate a more than proportional rise in the consumption of bushmeat. If wildlife is an inferior good ($\varepsilon_I < 0$), then income growth will have the opposite effect – as income would increase, the quantity of bushmeat consumed would decrease. If bushmeat is a normal good, particularly a necessity ($0 < \varepsilon_I < 1$), then positive changes in income will lead to a less than proportional rise in the quantity of bushmeat demanded.

This study will estimate the impact of income on the demand for bushmeat by using a unique household survey from three villages – Misseke, Robanda, and Bonchugu, which are located on the western border, northeast of the western corridor, of the Serengeti National Park as can be seen in Figure 1. The Serengeti National Park is located on the border of Tanzania and Kenya and covers 14,763 km^2 (Holmern et al., 2004). Listed as a World Heritage Site and recognized as a UNESCO Biosphere Reserve, the Serengeti ecosystem is characterized by yearly migration of large ungulate

[2] Bushmeat hunting might also be driven by cultural factors or security reasons. Wildlife might destroy crops, causing the farmer to incur losses from crop damage (Ogutu, 2002). In this study, however, I assume that the impact of such factors on hunting patterns is insignificant.

populations, particularly wildebeest, zebra, and gazelle. The migratory pattern is related to the food supply for animals, which in turn is affected by rainfall. The migratory herds use the southern short grassland, which has low annual rainfall, during the wet season and the wooded northern grassland, with higher rainfall, during the dry season. Hunting in the area is prohibited, except for that organized by the Serengeti Regional Conservation Project (SRCP). Hunting licenses can be bought at the district authority office, but to receive permission an individual must own a firearm and have access to a vehicle – requirements that very few people can fulfill (Holmern et al., 2004). Members of the Kuryia and Ikomo tribes inhabit the villages surveyed in this study. Kuryia and Ikomo are primarily subsistence agro-pastoralists, which have only lived in the area for several generations. Both tribes have historically participated in hunting illegal wildlife and have consumed bushmeat, but it is not their primary livelihood. In these areas, cotton is grown as a cash crop, while sorghum, millet, and cassava are grown as primary basic grains (Kabigumila, 1998).

Unlike previous studies (Wilkie and Godoy, 2001; Apaza et al., 2002; Loibooki et al. 2002; East et al., 2005), I will look at both total consumption of bushmeat and consumption disaggregated by animal in order to test whether certain animals require different conservation strategies. Furthermore, while previous studies have chosen to look at short-term consumption (over three days or weekly), such analysis might not be representative of the overall consumption patterns as the species within the Serengeti National Park are migratory. In this study, data on annual consumption of bushmeat will be used in order to take seasonality into account and to achieve more reliable results.

II. Literature Review

A debate persists in the literature on the relationship between income and the demand and consumption of wildlife. It was long believed, as some of the first studies indicated, that there was a deeply rooted cultural preference for the consumption of bushmeat and that consumers were even willing to pay a price premium in relation to domestic meat (Chardonnet, 1995).[3] In certain societies, many see bushmeat as a symbol of wealth and cultural heritage and have historical traditions of hunting bushmeat (Geist, 1988; Robinson and Bennett, 2000; UNEP, 2008; Scoones et al., 1992). This classification of bushmeat as a superior good and the according relationship with income, however, have not been empirically proven.

Several empirical studies on the price and income elasticities of bushmeat consumption have been conducted in Amerindian societies among native Amazonians in Bolivia (Apaza et al., 2002; Godoy et al., 2009). Evaluating the effect of real income and wealth on wildlife consumption, Godoy et al. (2009) calculated an income elasticity of 0.002 and a wealth elasticity of 0.558, suggesting that increases in household wealth have a significantly positive effect on the consumption of bushmeat.[4] They attributed this to short term improvement in household wealth, such as the acquirement of guns and other hunting tools that improve the efficiency of hunting. Results from Wilkie and Godoy (2001) for households in the lower ranges of the income distribution support this finding. Using weekly consumption data from lowland Amerindian societies in Bolivia and

[3] Domestic meat refers to any meat raised and herded domestically. This primarily includes meat from pigs, cows, chickens, goats, and sheep.
[4] While Godoy et al. (2009) find income to not be statistically significant with a p-value of 0.8800, wealth is found to be statistically significant with a p-value of 0.0108.

Honduras, they find that the income elasticity of bushmeat is 0.040 for the lower ranges of the income distribution and 0.056 for the pooled sample, but -0.137 for the top half of the income distribution. Investigating the role of prices and wealth in consumer demand for bushmeat in Gabon using a recall period of three days, Wilkie et al. (2005) also find a relatively small income elasticity of bushmeat of 0.169, suggesting that bushmeat is a dietary norm (de Merode et al., 2004).

Similar to Wilkie and Godoy (2001), several other authors have found that the relationship between income and the consumption of natural resources does not follow a linear trajectory. Such studies have concluded that consumption of natural resources follows an inverted U-shape, which is also often referred to as the environmental Kuznets curve (Godoy et al., 1995; Demmer, 2002; Panayotou, 2003). On the demand side, as income rises we should be able to observe a shift from bushmeat to domesticated meat (Demmer, 2002). In the short run, there might be an increase in consumption of wild game, but after a certain threshold of income, consumption will decrease as people substitute bushmeat with other sources of protein. Wilkie and Godoy (2001) predict that income might both lower and increase the demand for wild game. Higher incomes allow the purchase of improved tools, which can reduce the amount of time needed to extract natural resources and thus increase the harvest rate (Godoy et al, 1995). Meanwhile, higher incomes associated with economic development would also mean that there are other economic activities available and would thus increase the opportunity cost of natural resource extraction (Demmer, 2002).

The price of close substitutes, such as livestock, also affects the income elasticity of demand. Results from Bolivia suggest that increasing consumer access to and reducing the price of livestock meat aids in decreasing the demand for bushmeat initially, but in the long run bushmeat consumption increases with a wealth elasticity of 0.061 (Apaza et al., 2002). Studies from Amerindian societies, however, are often not indicative of the situation in Sub-Saharan Africa, where there is an abundance of diseases and insects that affect livestock – the main substitute for bushmeat (Wilkie and Carpenter, 1999; East et al., 2005).

The main obstacle to decreasing demand for bushmeat seems to be the lack of other substitutes that could provide animal protein nutrients. As reported in Loibooki et al. (2002) in their study on patterns of bushmeat hunting by communities near the Serengeti National Park in Tanzania, 83% of respondents participated in illegal hunting activities to obtain food, with 79% of the respondents also indicating that they hunted to obtain meat for sale. Using a general linear model, Loibooki et al. (2002) find that participation in illegal hunting decreases as wealth, measured in terms of livestock per capita, increases and as protein substitutes and other sources of income become available. After conducting the Mann-Whitney *U* tests, they also find that poachers on average own fewer cattle, sheep and goats, and have a smaller herd of livestock than those who do not participate in illegal hunting. In Tanzania, particularly, agriculture and livestock do not provide the necessary amount of protein and thus require individuals to seek nutrients elsewhere by participating in illegal hunting (Nielsen, 2006).

For many subsistence households, the consumption of bushmeat is tied to its availability and relative cheapness. Some would prefer to eat domestic meat, but, due to its high price, are unable to afford it and are thus forced to satisfy their protein needs by consuming bushmeat. In Equatorial Guinea, for example, individuals view bushmeat as "dirty meat" and would change to domesticated meat if they were given the option (East et al., 2005). Here it is important to make the distinction between food state and food type. As studies indicate, individuals prefer to consume fresh rather than frozen meat (East et al., 2005). Since fresh beef is about 2-3 times the price of fresh bushmeat, wild meat becomes the meat of choice, particularly for low-income large households (Wilkie and Carpenter, 1999). Increases in household wealth shift the preference from bushmeat to the meat of domesticated animals or to lower frequencies of bushmeat consumption.

It is important to note, however, that studies in subsistence economies are often hindered by a lack of an income variable. Since income is difficult to measure in the absence of formal labor markets and in countries where the majority of individuals are subsistence farmers, most economists use wealth as a proxy for income, where wealth is defined by a basket of assets, such as the number of cell phones, bicycles, axes, machetes, beds, TVs, livestock, and type of stoves (Cavendish, 2000; Apaza et al., 2002; Wilkie et al., 2005; Ndengejeho, 2007). This hinders the analysis of the possibility of using income growth as a viable strategy to reduce wildlife consumption. Wealth, as defined by assets, cannot necessarily predict the effect that changes in disposable income will have on the household's consumption patterns.

Studies of other household characteristics, such as household size, education, and ethnicity, the potential effect of which is presented in the following section, have produced differing results. This is an indication that within every society there is a socio-economic differentiation that plays out (Shackleton and Shackelton, 2006). In addition, many of the results have been hindered by inadequate household data, particularly a clearly defined income variable. This study will attempt to provide a clearer picture of the impact of income on the demand for bushmeat by using a detailed household survey from areas neighboring the Serengeti National Park in Tanzania. Using annual aggregated consumption and consumption disaggregated by the four most popular animals, the results presented here will take into account the seasonality of migration, as well as differences that may be linked to each animal. By establishing the factors contributing to the consumption patterns of bushmeat, it will be possible to improve conservation efforts and to reduce the consumption of wildlife.

III. Theoretical Framework

It is often difficult to predict the consequence of a change in income on the consumption patterns in semi-commercialized rural economies, where households produce primarily agricultural products both for sale and consumption. Since 1975, economists have been working on developing microeconomic models that would combine consumption, production, and labor decisions of households. The agricultural-household model was first introduced after an unexpected finding in the Japanese rural sector, where an increase in the price of a staple did not significantly increase the marketed surplus (Singh et al., 1988). The resulting model combined both production and consumption decisions, in which the household is both a producer and a consumer. As a producer, the household chooses the allocation of labor and other inputs to the production of a certain good. As a consumer, it chooses the allocation of its income to purchase goods. For the purpose of this analysis, the formal agricultural household model as outlined in Singh et al. (1988) will be modified for bushmeat.

There are several characteristics of the household model that I must first outline. The term household is confined to those family members living in a single abode. In this case, I assume the existence of a unified household, where there is unanimous decision-making and there is no negotiation within the household. The model operates under the assumption that there are complete markets for labor, outputs, inputs, and credit. The presence of complete markets guarantees that households can sell their labor and outputs. It also suggests that households are price-takers and have perfect price information.

The assumption of complete markets and exogenous prices allows for production decisions to be made independently of leisure and consumption. This is known as the separability property. The household first makes the production decisions, and then subsequently the income is used to determine the consumption decision. The separability property allows for separate specifications of the consumption and production components of the model and for the derivation of demand equations (Strauss, 1983). While production decisions over labor affect consumption decisions through household profits in the income constraint, consumption decisions do not affect production decisions. Production is independent of household preferences and income. Consumption and labor-supply are determined by the household's income, which to a large extent is determined by the profits the household incurs from its hunting activities. This relationship is referred to as the profit effect and implies that there is a sequence in the decision-making process (Singh et al., 1988).

Let us consider a household that hunts bushmeat using two inputs: a fixed amount of available hunting area and labor. The household sells a portion of their bushmeat and consumes the rest. It can also purchase bushmeat from the market.[5] The household allocates time between hunting, marketed labor, and leisure, where leisure is more commonly referred to as "home time" and can be allocated to child rearing, religious and cultural events, and household chores (Sadoulet and De Janvry, 1995). Since there are complete markets, we assume that the household can sell bushmeat and labor at a fixed rate. Assuming that the household is profit-maximizing, it will want to hunt bushmeat until the marginal cost of hunting equals the marginal revenue. [6] I also assume that the household wants to maximize its utility and wants to consume a certain combination of bushmeat and leisure located on the highest attainable indifference curve.

As illustrated in Figures 2 and 3, the profit line π (p, w, A) shows the value of different combinations of leisure and bushmeat. The slope of the profit line is the relative price of bushmeat and leisure, and profits are maximized at the point at which the profit

[5] This factor is important in distinguishing between net buying and net selling households, since a change in price will have different effects in both cases. A higher price, for example, lowers the welfare of a net buyer, but raises the welfare of a net seller.
[6] Theodore Schultz (1964) first described subsistence farmers as "poor but efficient," indicating that given their constraints (labor, technology, capital, education) they allocate their resources efficiently. Like firms, subsistence farmers also want to either minimize costs or maximize profits.

line is tangent to the production function $Q_B=f(L_B,A)$. Given a price of bushmeat, households can decide the amount they poach independently of the amount they consume because they are certain that they can purchase or sell the meat. Thus, the only constraint to maximizing utility that the household faces is income (or profit).

Different households hold different preferences depending on their social and demographic characteristics. In Figure 2, the diagram represents the preferences of household_1. Utility_1 is maximized at the point where consumption of bushmeat is equal to C_1* and the family supply of labor is L_1*. In this case, the household only participates in hunting and does not need to sell its labor in the market in order to maximize its utility. Figure 3 depicts the preferences of household_2. Utility_2 is maximized at the point where consumption of bushmeat is equal to C_2* and the family supply of labor is L_2*. Given this particular indifference curve, the household has a higher demand for bushmeat than it can satisfy with its production and thus must purchase bushmeat in the market. In order to do so, the household must sell its labor as represented by L_M.

I can formally represent these decisions by deriving the demand for the consumption of bushmeat. In a simple two-good economy, the household wants to maximize its Cobb-Douglas[7] utility function represented by:

$$U(C_B,l;z) = zC_B^{\beta}l^{1-\beta} \tag{1}$$

by consuming bushmeat (C_B) and leisure *(l)*. The shape of the indifference curve is determined by household characteristics (z), which include education[8], household size[9],

[7] The Cobb-Douglas utility function does not allow for inferior goods, and thus the model simply provides a conceptual framework used to analyze the effects of income on the demand for bushmeat.

ethnicity[10], and other factors[11]. The quantity of bushmeat produced (Q_B) is determined by the amount of labor allocated to hunting (L_H) and the number of available hunting areas within the region (A), where:

$$Q_B(L_H, A) = AL_H \quad (2)$$

Leisure is "produced" by choosing not to allocate labor to hunting and to the market.

Household utility is also subject to a time constraint:

$$T = \mathbf{L} + l \quad (3)$$

where T is total fixed time that can be spent either on labor (**L**) or leisure *(l)*. **L** represents total family labor, which includes labor allocated to hunting (L_H) and labor allocated to other income earning activities, such as agriculture or marketed labor.

Household utility is also subject to an income constraint:

$$P_B(Q_B - C_B) + w(\mathbf{L} - L_H) = 0 \quad (4)$$

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[8] Le Breton et al. (2006) find that individuals who spend more time in formal education are more likely to kill and eat wild animals. Bandyopadhyay and Shyamsundar (2004), on the other hand, determine that education increases the opportunity cost of natural resource extraction and thus has a negative relationship with the consumption of natural resources.

[9] There is a general consensus within the literature about the positive relationship between household size and natural resource consumption. Nielsen (2006) finds that household size plays an important role in determining whether or not individuals participate in illegal hunting. He finds that hunters' households are usually larger in size and contain more adults and children. Subsequently, such households require more meat.

[10] While studying the importance of religion and ethnicity in Equatorial Guinea, East et al. (2005) report that only ethnic origin is statistically significant.

[11] East et al. (2005) determine that individuals born in the city district where the hunting is occurring are less likely to butcher and consume bushmeat than individuals that move to that city district. Distance of the households from the hunting area is also found to be significant by Shively (2002), with hunting efforts and frequency declining as distance increases.

where w is the market wage. If a household is a net seller of bushmeat, then Q_B-$C_B > 0$ and < 0 if the household is a net buyer of bushmeat. In addition, if the household only hunts and does not sell its labor in the market, then $L=L_H$.

By combining equations (2), (3), and (4), I obtain the full income constraint:

$$P_B A L_H + wT - wl - wL_H = P_B C_B \tag{5}$$

In order to derive the demand function of the consumption of bushmeat and leisure, I need to derive the first order conditions by maximizing (1) subject to (5) using the Lagrangian:

$$\mathrm{L} = zC_B^{\beta} l^{1-\beta} - \lambda\left[P_B C_B + wl - P_B A L_H + wL_H - wT\right] \tag{6}$$

The first order conditions are:

$$\frac{\partial U}{\partial C_B} : z\beta C_B^{\beta-1} l^{1-\beta} - \lambda P_B = 0 \tag{7}$$

$$\frac{\partial U}{\partial l} : z(1-\beta) C_B^{\beta} l^{-\beta} - \lambda w = 0 \tag{8}$$

$$\frac{\partial U}{\partial L_H} : \lambda P_B A - \lambda w = 0 \tag{9}$$

$$\frac{\partial U}{\partial \lambda} : P_B C_B + wl - P_B A L_H + wL_H - wT = 0 \tag{10}$$

From (7) and (8) I obtain:

$$\frac{\beta l}{(1-\beta) C_B} = \frac{P_B}{w} \tag{11}$$

Equation (11) represents the marginal rate of substitution of leisure for bushmeat and is equal to the ratio of the price of bushmeat and the wage rate.

From (9):

$$P_B A = w \tag{12}$$

which says that the marginal product of hunting labor equals the prevailing wage rate.

To derive the demand function for C_B, I use (10), (11), and (12):

$$P_B C_B + w\left(\frac{(1-\beta)C_B P_B}{\beta w}\right) - P_B A L_H + P_B A L_H - wT = 0 \tag{13}$$

$$P_B C_B\left(1+\frac{1-\beta}{\beta}\right) = wT \tag{14}$$

$$C_B = \frac{wT}{\left(1+\frac{1-\beta}{\beta}\right)P_B} \tag{15}$$

$$C_B = \frac{\beta w T}{P_B} \tag{16}$$

The demand for the consumption of bushmeat is described by equation (16). Consumption is driven by the wage rate, total time available in a household, and the price of bushmeat.

In order to obtain the demand function in linear form, the natural logarithm of (16) is taken:

$$\ln C_B = \ln w + \ln T + \ln \beta - \ln P_B \tag{17}$$

Equation (17) is the theoretical guiding equation.

IV. Empirical Framework

For ease of derivation, the above theoretical model assumes that households only consume bushmeat and leisure. This assumption, however, is not realistic. Households usually make decisions regarding the consumption of bushmeat relative to other available substitutes for protein, and I would expect consumption of bushmeat to decrease as consumption of protein substitutes increase. Therefore, the consumption of other meats and their respective prices must be included in the guiding equation. I must also control for household characteristics, such as education and household size. Combining the existing empirical models applied in previous studies (Wilkie and Carpenter, 1999; Wilkie et al., 2005) with the formally derived demand function, the following represents the more comprehensive guiding equation:

$$\begin{aligned}\ln consumption_{bushmeat} &= \beta_1 + \beta_2 \ln consumption_{otherprotein} + \beta_3 \ln price_{bushmeat} + \beta_4 \ln income \\ &+ \beta_5 \ln householdsize + \beta_6 education_{female} + \beta_7 education_{male} + \beta_8 huntingtrips + \beta_9 villagedummy + \varepsilon \end{aligned} \quad (18)$$

The number of hunting trips per year is a proxy for the labor allocated to hunting and the village dummy is included to control for village-level unobservables.

OLS is the standard estimation technique used to measure the connection between income and the consumption of bushmeat (Godoy et al., 1995; Wilkie and Carpenter, 1999; Apaza et al., 2002; East et al., 2005; Wilkie et al., 2005). In this study, it is important, however, to take into account the many zero observations for consumption of each animal. While OLS is the most common approach used to measure the relationship between the consumption of wildlife and income, the tobit model, as proposed by Godoy et al. (2001), is more appropriate for studies in which there are many zero observations for the dependent variable.[12] The tobit model produces better estimates for data that is left censored at 0 by using maximum likelihood to combine the probit and regression components of the log-likelihood function (Baum, 2006).

Previous studies have not separated bushmeat by animal. In this study, I will first estimate the demand for aggregated bushmeat by using OLS and tobit. I will then estimate the demand functions for wildebeest, zebra, topi, and buffalo separately using a seemingly unrelated regression. A seemingly unrelated regression (SUR) is usually performed to estimate a similar specification for several different units, such as a demand function for several commodities. The equations are estimated jointly to test cross-equation restrictions and to gain more efficient estimates than those of OLS since the error terms across equations might be contemporaneously correlated (Baum, 2006). The correlation among the error terms might be a result of correlated shocks to households, such as household income, that cannot be observed. Seemingly unrelated regressions are frequently used in estimating demand functions for food. Wilde et al. (1999), for

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[12] Although it is often difficult to determine the different sources of zero observations from the survey data, such observations must be taken into account in order to obtain consistent estimates. In cross-sectional consumption data, zero observations can be explained by three occurrences: a corner solution, true non-consumption or non-participation, and infrequency of purchase. The corner solution occurs when the household chooses not to consume the particular food at the given price and existing income. True non-consumption or non-participation refers to the household's decision, which is made independent of income and price levels, to forego the consumption of a certain product. The third explanation can be attributed to products that have purchase cycles longer than the period length of the survey (Obayelu et al., 2009). For this particular study, only the first two are applicable since I do not expect bushmeat to have a purchase cycle longer than a year.

example, break down food into seven subgroups and estimate the effect of income and food programs on dietary quality using SUR. Several other studies have found SUR to be a better estimation technique than OLS when a good is disaggregated into several demand functions (Hein and Wessels, 1990; Eales and Unnevehr, 1992).

For the purposes of this study, it is also important to determine whether there are inherently different unobservable characteristics between the poachers and the non-poachers that determine their hunting behaviors. The Heckman model tests for this by treating the unobserved selection factors as a problem of specification error or omitted variable bias (Baum, 2006). The Heckman model, however, cannot be performed in the following study due to the small sample size and the lack of the exogenous identifier as the households participating in the survey are all poachers or have poached in the past. This issue will be discussed in more depth in subsequent sections.

V. Summary Statistics

The data used in this study originate from a cross-sectional household survey conducted in areas near the Serengeti National Park in Tanzania in March of 2009 by the Frankfurt Zoological Society. The survey sampled 102 households from three neighboring villages: Robanda, Bonchugu, and Misseke. The sample of households was taken from a newly established network of conservation community banks (CoCoBas). CoCoBas are essentially communal micro-credit establishments to which every member must contribute a monthly share and is then able to receive a loan of up to three times the amount that he has contributed by that time. One of the requirements of joining a cocoba is that the individual must no longer participate in illegal hunting. The survey consisted of 46 questions on demographic characteristics of the household and its consumption patterns. It was carried out by native Swahili speakers and on average took a little over an hour to complete. The answers were then compiled and translated into English.

There are a number of potential shortcomings of this data set. By drawing the sample from a group of poachers or ex-poachers, the study generates a selection bias, however, given the data restrictions, specifically the lack of a non-poacher control group, this cannot be accounted for. Given this selection bias, empirical estimates may over-estimate bushmeat consumption and exaggerate own and cross price effects. Furthermore, households might understate the amount of bushmeat consumed. This can be done for two reasons. First, due to a recall period of a year, households might not be able to recall an accurate amount of consumption. This represents the tradeoff between accuracy and taking into account the seasonality factor caused by the migratory nature of the species. Second, households might choose to report lower levels of hunting in fear of possible punishment or social stigma. This might be particularly true for lower-income households. These two factors may mitigate the over-estimation resulting from selection. This will hinder the reliability of our results if understatement varies systematically, for example with income.

The dependent variable is the yearly consumption of bushmeat in kilograms. The independent variables include the number of people in the household, education of the female head, education of the male head, livestock consumed, fish consumed, and income. The explanations of the variables and the summary statistics for these variables can be seen in Tables 1 and 2 respectively. The data were inspected for irregularities and inaccuracies, which could be a result of measurement or coding errors, using histograms and summary statistics. No such observations were found. Total income was calculated using income from formal employment, the value of all agricultural produce, and monetary gifts and remittances. The average annual household income is 305,563.50 TZS (approximately 228 USD). One household is an outlier with a reported annual income of 3,084,999.00 TZS (approximately 2,310 USD).

The average household size consists of 8 individuals and has a standard deviation of 3.96, with a mean household age of 18.42. This indicates that the households are fairly large, but young. On average, female household heads receive 5 years of education, while male household heads receive 6 years of education. Out of the 102 households, 78 practice Christianity, while the rest report no religious beliefs.

Consumption is defined as any meat or fish purchased, hunted, caught or otherwise obtained by the household. Bushmeat and chicken are the most popular sources of protein, with the average consumption of bushmeat being 186.887 kilograms. The average annual consumption of fish, on the other hand, is 5.882 kilograms. The standard deviations for both the amount of fish and bushmeat consumed are quite high. Out of the 94 households, 34 did not consume any bushmeat during the previous year. On average, households made 3 hunting trips during the previous year.

Hunting data are available for 11 different animals out of which wildebeest, buffalo, topi, and zebra are the four most popular sources of bushmeat. While the average quantity of both topi and buffalo consumed are greater than the average quantity of zebra, 24 households hunted for zebra compared to 16 and 12 for buffalo and topi respectively. For those households that did not report the price of bushmeat, an average village price of the particular meat was calculated, assuming that the prices within the villages did not differ significantly.

To determine whether there are inherently different characteristics of those who consume bushmeat and those who do not, separate summary statistics are presented for the two groups in Table 3. Hunters of bushmeat have relatively higher incomes, are larger in size, and are less educated.[13]

VI. Results and Analysis

Due to missing information on the consumption of livestock, the number of cows, goats/sheep, and chickens slaughtered in a year are used as a proxy for the consumption of livestock. Prices of protein substitutes are also not available and thus cannot be included in the regression. Although studies (Apaza et al., 2001; Wilkie and Godoy, 2005) have found that the price of fish and prices of other substitutes do not significantly affect the consumption of bushmeat, their absence might potentially generate omitted variable bias.

Prior to running the regressions, several transformations were made to the variables. Due to the small sample size and a large number of reported zeros for certain variables, a double log form is not possible. Thus a semi-log form is applied. The natural

[13] Out of 94 households, 17 households indicated that they killed wildlife because it injured their livestock and 1 household reported that wildlife damaged its crop. This supports my assumption that hunting is not primarily driven by security reasons.

logs of total income and household count were taken in order to achieve a more normal distribution. The natural logs of prices were also taken in accordance with theory. The correlation coefficients were calculated to test for multicollinearity and are presented in Table 4. Instances of multicollinearity were found between the prices of wildebeest and zebra and the prices of topi and buffalo.[14] Both theory and literature, however, indicate that the prices of bushmeat must be included in the regression and thus no corrective action was taken.

After running the first regression with the natural logarithm of total bushmeat consumed during the past year (in kilograms) as the dependent variable, the results were tested for heteroskedasticity and omitted variable bias. Since the Breusch-Pagan test for heteroskedasticity showed that the assumption of constant variance of the error term was violated, Huber-White robust standard errors were applied. The null hypothesis of the Ramsey test could not be rejected indicating that there is no evidence of omitted variable bias. The robust results are reported in Table 5.

Since consumption is measured in absolute terms, while income is in the natural log form, the coefficient for income does not represent the income elasticity. The coefficient had to be transformed and the income elasticity was calculated to be 0.051. This indicates that bushmeat is a necessity, since ε_I is only slightly greater than 0, and a change in income will result in a less than proportional increase in the consumption of bushmeat. The coefficient for hunting trips is positive and statistically significant as expected, indicating that the amount of bushmeat consumed increases as the number of

[14] The correlation coefficient for the prices of wildebeest and zebra is 0.881, while the correlation coefficient for the prices of topi and buffalo is 0.952.

hunting trips a household takes rises. The negative and statistically significant coefficient for fish consumed suggests that bushmeat and fish are substitutes.[15] As households consume more fish, they decrease their consumption of bushmeat.

To test the validity of OLS estimates and to take into account the many zero observations for the consumption of bushmeat, a tobit model was conducted for aggregated bushmeat. The results are presented in Table 6. The results are similar to the OLS results, except for the magnitude of the coefficients. The signs of coefficients, however, are consistent with OLS results. The estimated income elasticity for bushmeat with the tobit model is 0.023. This supports the results obtained with OLS and indicates that bushmeat is indeed a necessity in the region.

In order to test whether these results held for the consumption of wildebeest and zebra, the two most common sources of bushmeat, a tobit model was conducted with the consumption of wildebeest and zebra as the dependent variables.[16] Due to the large number of observations where households reported zero consumption of each animal, the natural log of consumption was not taken in order to retain the sample size. The results are presented in Table 7. Cross price, own price, and income elasticities were calculated and are presented in Table 10.

The own-price elasticity of wildebeest is negative, while the cross-price elasticities are positive for zebra and topi and negative for buffalo. This pattern is also true for the own and cross price elasticities for zebra. While the own-price elasticity for

[15] The price of fish is needed to further test whether bushmeat and fish are indeed subsitutes.

[16] The tobit regression could not be applied to buffalo and topi due to the small number of non-zero observations. An OLS regression was conducted for the consumption of wildebeest, zebra, topi, and buffalo, the results of which are reported in Appendix A Table 1.

zebra is negative, the cross-price elasticties are positive for wildebeest and topi and negative for buffalo. This suggests that as the prices of wildebeest and zebra rise, households reduce their consumption of the two animals. This finding is unexpected, since consumption in this study is primarily defined as bushmeat hunted. As a result, I would expect households to hunt more if the prices of bushmeat increased. These contrary results, however, can be explained by the possible measurement error caused by using the average village price for the households that did not report the price of bushmeat.

Income is only statistically significant for the consumption of wildebeest with an income elasticity of 0.857. This indicates that wildebeest is a normal good, the consumption of which increases as income rises. While the coefficient for income is not statistically significant for zebra, the income elasticity for zebra suggests that it is also a normal good. The positive income elasticities are consistent with those obtained from both the aggregated OLS and tobit regressions, in which bushmeat was a necessity.

The amount of hunting trips per year has a positive and significant coefficient for wildebeest. This result is consistent with the general trends of illegal hunting near the Serengeti National Park, where wildebeest is hunted most frequently and is the most common source of bushmeat. Household size is only significant for wildebeest, for which it has a positive coefficient as suggested by previous studies. Education of both the female and the male heads is insignificant for both wildebeest and zebra. Cows and chicken do not have a statistically significant effect on the consumption of wildbeest and zebra. The statistically significant negative coefficients on goat/sheep slaughtered and fish consumed, the other two substitutes for bushmeat, indicate that increasing the availability of goat/sheep and access to fish might be effective in reducing the consumption of wildebeest. [17] The two regressions were also performed with religion, a dependency ratio[18], and an income-squared variable to test for the hypothesized inverted U-shape relationship. The variables, however, were insignificant and did not significantly change the estimates of the other variables.

In order to take into account the possible measurement error that can be caused by using transitory rather than permanent income, as measured by wealth and assets, a tobit regression with livestock owned as an independent variable was also conducted.[19] The results are presented in Table 8. While wealth is generally measured by the total monetary value of a basket of modern assets (TV, cell phone, radio, mosquito nets, machetes, bicycle) and traditional assets (cows, pigs, ducks, hens, canoes), I do not have the available resources to calculate the total worth of the basket (Apaza et al., 2002). Thus, I choose to use traditional assets as a proxy for wealth. The livestock variable represents the total number of cows, pigs, chickens, and ducks that the household owns. The results are similar to the tobit estimates obtained using only transitory income.

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[17] It is worth noting, however, that livestock wealth might not be a viable conservation strategy and will not necessarily improve conservation efforts. It is important to empirically test the effects of the unsustainable patterns of bushmeat hunting and the negative impact of increased livestock herding on the environment in order to determine whether the effect of increased livestock wealth on bushmeat consumption outweighs its environmental costs. In addition, while the labor allocated to hunting does not compete with that allocated to agriculture as hunting generally occurs during the agricultural off-season, animal husbandry requires a steady amount of labor throughout the year. Households that are labor-constrained might thus not be able to raise more livestock.

[18] The dependency ratio takes into account the relative contributions of different members of the household with regard to consumption and production. It is calculated as the ratio of the non-working population (under 15 and over 65) over the working population (15-65 years).

[19] An OLS regression was also conducted using livestock as an independent variable for the four most popular animals. The results are reported in Appendix B Table 2.

Livestock is insignificant for both wildebeest and zebra and does not statistically change estimates of other independent variables.

In order to test the validity of tobit estimates, a seemingly unrelated regression for consumption of the four animals was conducted. The results are presented in Table 9 and the calculated elasticities are reported in Table 10. Income is only statistically significant for wildebeest, but the income elasticity is positive and less than 1 for all four animals. All four income elasticities suggest that bushmeat is a necessity and that consumption of wildebeest, zebra, topi, and buffalo will increase as income rises. It is interesting to note that the coefficient for hunting trips for zebra is now statistically significant and negative. This suggests that households that hunt more often do not hunt for zebra, but rather, as the consistently significantly positive coefficient for hunting trips for wildebeest indicates, might instead consume more wildebeest. The coefficients for goat/sheep slaughtered and fish consumed are now significant at the 1% and are negative. This again supports the hypothesis that increasing livestock and improving access to other sources of protein might result in the reduction of the consumption of bushmeat.

The overall insignificance of education levels indicates that higher education does not raise the opportunity cost of hunting. This is also concluded by Nielsen (2006), who notes the importance of opportunity costs in establishing the intensity of exploitation, particularly in Tanzania, where there is a lack of other economic activities. When bushmeat is itself both a source of cash income and food (cited as the two most popular reasons for hunting in Loibooki et al. (2002)), without economic activities that could generate the same income and provide food for the household, hunters are not experiencing any opportunity costs (Hofer et al., 2000).

VII. Conclusion and Implications

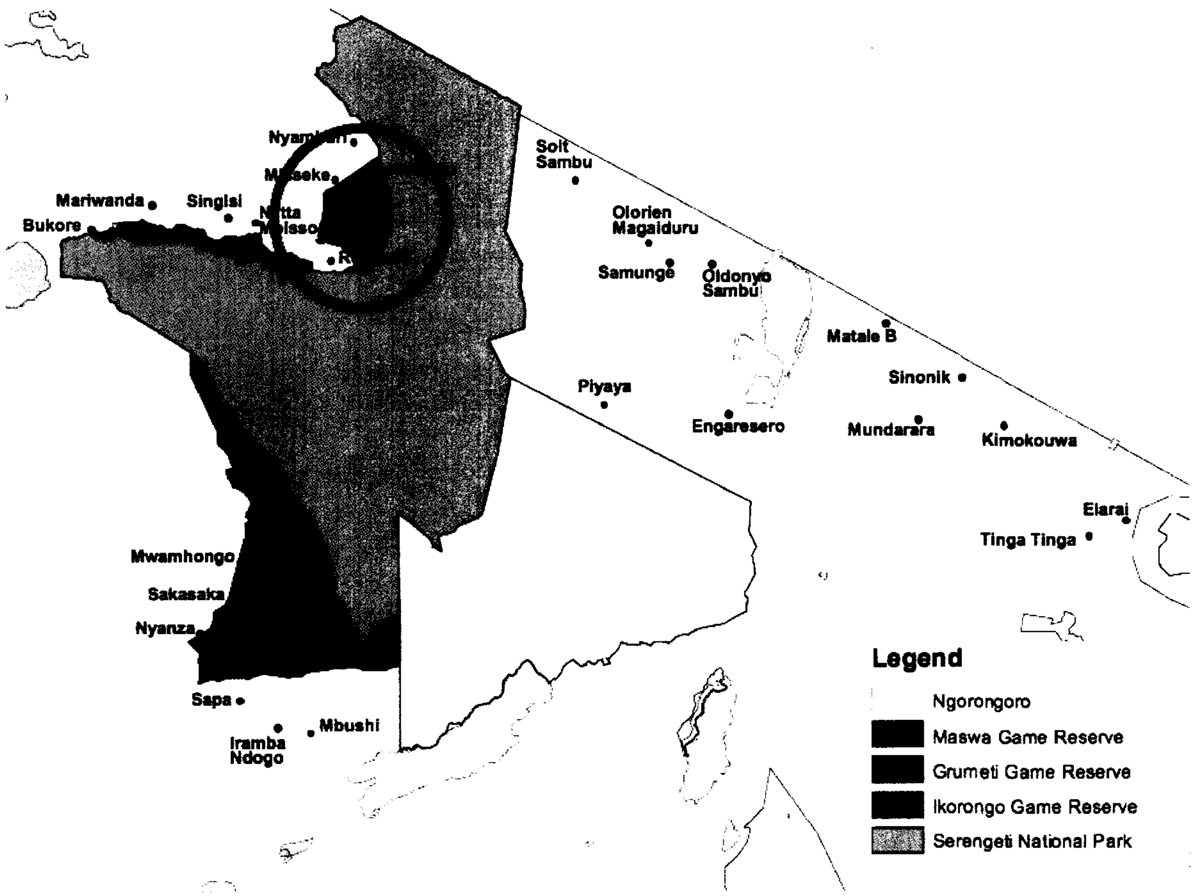
The purpose of this study was to determine the impact of income on the consumption of bushmeat and to test whether income growth could be a viable conservation strategy to reduce the demand for bushmeat. Using a cross-sectional household survey from three villages neighboring the Serengeti National Park, I estimated the demand functions for the general consumption of bushmeat, as well as consumption for the four most popular animals: wildebeest, zebra, buffalo, and topi. Based on the results from both the aggregated and disaggregated demand functions, bushmeat is a necessity in the region, implying that increases in income would lead to less than proportional increases in consumption. Income growth alone is thus not a viable conservation strategy. As results from the disaggregated tobit model and SUR indicate, increasing the amount of livestock, particularly goats and sheep, as well as access to fish, might aid in reducing the demand for bushmeat. Such strategies might include programs that establish communal livestock farms, such as those currently pursued by cocobas. It is important, however, to empirically test whether the reduced consumption of bushmeat outweighs the environmental costs of increased livestock in order to determine whether livestock is a viable conservation strategy. Furthermore, animal husbandry might compete with agricultural production and in labor-constrained households increasing livestock might not be possible without lowering agricultural output.

Another possible strategy to reduce the consumption of bushmeat would be to lower the price of permits and increase monitoring efforts, in order to ensure that hunting quotas and regulations are adhered to. This, however, would also need to be done in conjunction with making other protein sources available, as Fa et al. (2003) indicate that lowering the consumption of bushmeat to sustainable levels would significantly decrease the household intake of protein.

The relatively small sample size with few non-zero consumption observations hinders our overall analysis and the significance of our estimates. Increasing the sample size and including time-series data would benefit further research. Longitudinal data would allow us to test for short term versus long-term effects of changes in income. The addition of a non-poacher control group would also improve our estimation by eliminating the selected variable bias. Data on prices of substitutes for bushmeat would also be important to test whether bushmeat is consumed due to a lack of other substitutes and/or their relatively high price, as suggested by previous studies (Loibooki et al., 2002; Nielsen, 2006), and to determine if indeed livestock and fish could decrease the consumption of bushmeat. In the absence of a formal income variable for most households in the sample, further research should also include the development of a better proxy for permanent income/wealth. Data on the monetary value of modern assets owned by the household would allow us to generate a more appropriate measure of household wealth.

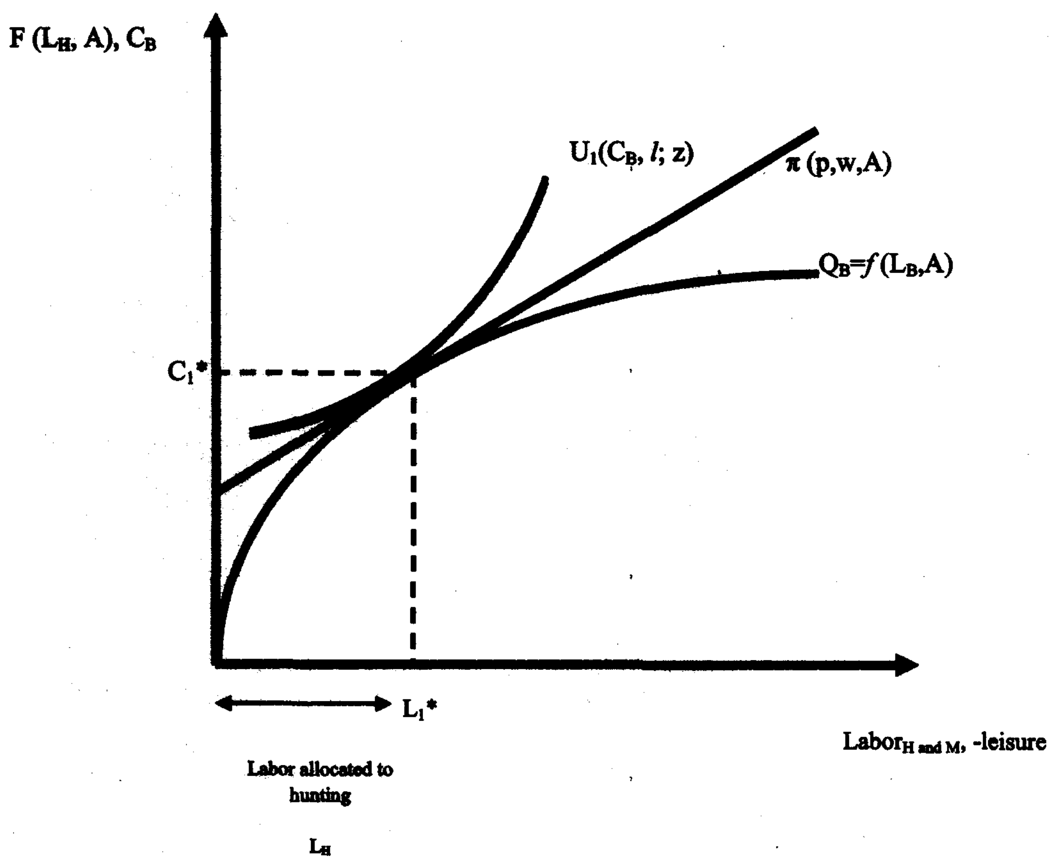
VIII. Figures and Tables

Figure 1: Map of the Study Area



Source: The Whole Village Project (2006).

Figure 2. Graphical Representation of the Household Model for Household$_1$



Source: Benjamin (1992)

Figure 3. Graphical Representation of the Household Model for Household$_2$

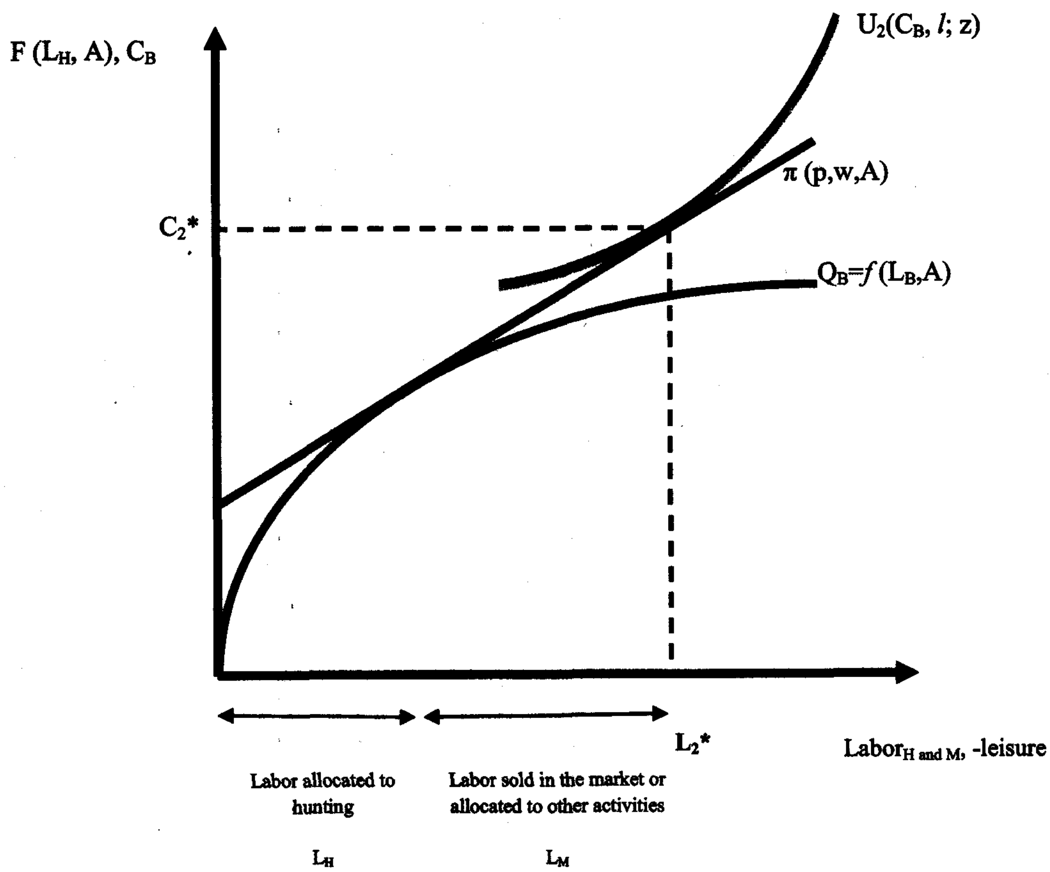


Table 1: Explanations of the Variables

Bushmeat Consumed	Total amount of bushmeat (in kilograms) consumed by the household during the previous year.
Wildebeest Consumed	Total amount of wildebeest hunted (in kilograms) during the previous year.
Buffalo Consumed	Total amount of buffalo hunted (in kilograms) during the previous year.
Zebra Consumed	Total amount of zebra hunted (in kilograms) during the previous year.
Topi Consumed	Total amount of topi hunted (in kilograms) during the previous year.
Wildebeest Price	The price in TZS per kilogram of wildebeest. In regression results represents the natural log of wildebeest price.
Zebra Price	The price in TZS per kilogram of zebra. In regression results represents the natural log of zebra price.
Topi Price	The price in TZS per kilogram of topi. In regression results represents the natural log of topi price.
Buffalo Price	The price in TZS per kilogram of buffalo. In regression results represents the natural log of buffalo price.
Total Income	The sum of income from formal employment, value of agricultural produce, and monetary gifts and remittances. In regressions results represents the natural log of total income.
Hunting Trips per Year	Total amount of hunting trips made during the previous year.
Chicken Slaughtered	Number of chickens slaughtered in the previous year.
Goat/Sheep Slaughtered	Number of goat/sheep slaughtered in the previous year.
Cows Slaughtered	Number of cows slaughtered in the previous year.
Fish Consumed	Total amount of fish consumed (in kilograms) during the previous year.
Education of Female Head	Education (in years) of the oldest working-age female in the household.
Education of Male Head	Education (in years) of the oldest working-age male in the household.
Household Count	Number of individuals considered to be part of the household as reported by the respondent.

Table 2: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Bushmeat Consumed	186.887	535.143	0	2535
Wildebeest Consumed	53.51	176.41	0	1080
Zebra Consumed	27.71	90.96	0	600
Topi Consumed	30.45	198.88	0	1875
Buffalo Consumed	34.21	137.68	0	1000
Hunting Trips per Year	3.088	11.877	0	50
Fish Consumed	5.882	26.192	0	252
Total Income	305,563.50	431,286.80	0	3,084,999
Wildebeest Price	4482.48	1237.158	500	8000
Zebra Price	4564.706	1298.621	500	8000
Topi Price	5533.422	855.438	1000	8000
Buffalo Price	5900.441	1024.896	1000	9000
Mean Household Age	18.419	5.074	10.6	36.6
Chicken Slaughtered	2.510	4.145	0	25
Goat/Sheep Slaughtered	0.853	2.495	0	20
Cow Slaughtered	0.216	0.74	0	5
Household Count	8.127	3.964	2	25
Education of Female Head	5.363	3.177	0	13
Education of Male Head	6.160	3.430	0	13

Notes: 94 Observations

Table 3: Summary Statistics Separated by Consumers and Non-Consumers

	Consumers				Non-Consumers			
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Fish Consumed	12.036	47.610	0	252	3.603	9.583	0	48
Total Income	363,644.50	576,422.10	0	3,084,999	279,882.60	365,365.70	0	1,812,000
Cow Slaughtered	0.286	0.600	0	2	0.192	0.793	0	5
Chicken Slaughtered	1.893	4.358	0	20	0.452	1.014	0	5
Goat/Sheep Slaughtered	2.321	2.945	0	10	2.562	4.561	0	25
Household Count	9.964	4.014	5	20	7.384	3.744	2	25
Education of Female Head	4.679	3.232	0	7	5.603	3.157	0	13
Education of Male Head	5.464	3.260	0	11	6.082	3.715	0	13

Notes: 60 households consumed bushmeat, 34 households did not

Table 4: Correlation Coefficients

	Wildebeest Price	Zebra Price	Topi Price	Buffalo Price	Total Income	Hunting Trips per Year	Chicken Slaughtered	Goat/Sheep Slaughtered	Cows Slaughtered	Education of Female Head	Education of Male Head	Village Dummy	Household Count	Fish Consumed
Wildebeest Price	1.000													
Zebra Price	0.881	1.000												
Topi Price	0.489	0.451	1.000											
Buffalo Price	0.425	0.421	0.952	1.000										
Total Income	0.102	0.109	0.035	0.038	1.000									
Hunting Trips per Year	-0.159	-0.202	0.082	-0.003	0.306	1.000								
Chicken Slaughtered	0.172	0.182	0.035	-0.024	0.051	-0.121	1.000							
Goat/Sheep Slaughtered	-0.062	-0.112	0.201	0.233	0.048	0.003	0.210	1.000						
Cows Slaughtered	-0.107	0.024	0.090	0.173	0.048	-0.101	0.186	0.175	1.000					
Education of Female Head	0.142	0.104	-0.081	-0.142	0.092	-0.015	0.053	-0.113	0.036	1.000				
Education of Male Head	-0.025	-0.056	-0.138	-0.201	0.108	0.089	0.317	0.123	0.014	0.543	1.000			
Village Dummy	-0.110	-0.152	-0.374	-0.524	-0.075	-0.026	0.207	-0.224	-0.171	0.380	0.190	1.000		
Household Count	-0.202	-0.257	0.150	0.174	0.039	0.302	0.248	0.092	0.401	-0.105	-0.076	-0.047	1.000	
Fish Consumed	-0.021	0.001	-0.059	-0.098	-0.092	-0.018	0.275	-0.184	-0.142	-0.132	-0.125	0.062	0.214	1.000

Table 5: OLS Regression Results for Total Bushmeat Consumed

Variable	Coefficient
Wildebeest Price	101.111
	(0.32)
Zebra Price	103.021
	(0.36)
Topi Price	-795.399
	(0.77)
Buffalo Price	777.259
	(0.75)
Total Income	9.612
	(1.75)*[20]
Hunting Trips per Year	38.290
	(3.09)***
Chicken Slaughtered	-2.807
	(0.19)
Goat/Sheep Slaughtered	-27.925
	(0.75)
Cows Slaughtered	-51.72
	(0.72)
Fish Consumed	-3.391
	(1.71)*
Education of Female Head	-10.648
	(0.54)
Education of Male Head	17.207
	(0.96)
Robanda Village	-235.429
	(1.43)
Misseke Village	-165.855
	(0.73)
Household Count	117.172
	(0.90)
Constant	-1,697.58
	(0.68)
R-squared	0.34

Notes: 94 Observations
Robust t statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

[20] The calculated income elasticity is 0.051.

Table 6: Tobit Regression Results for Total Bushmeat Consumed

Variable	Coefficient
Wildebeest Price	55.833
	(0.08)
Zebra Price	81.134
	(0.12)
Topi Price	-1,221.77
	(0.52)
Buffalo Price	1,747.72
	(0.73)
Total Income	4.359
	(1.62)*[21]
Hunting Trips per Year	85.594
	(2.58)**
Chicken Slaughtered	-3.406
	(0.06)
Goat/Sheep Slaughtered	-139.298
	(1.37)
Cows Slaughtered	-175.209
	(0.69)
Fish Consumed	-2.946
	(1.74)*
Education of Female Head	-25.429
	(0.35)
Education of Male Head	33.206
	(0.49)
Robanda Village	-6,416.47
	(0.05)
Misseke Village	-1,410.77
	(2.07)**
Household Count	627.573
	(1.33)
Constant	3,007.77
	(0.48)

Notes: 94 Observations
Robust t statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

[21] The calculated income elasticity is 0.023.

Table 7: Tobit Regression Results for Wildebeest and Zebra

	Coefficient	
Variable	Wildebeest Consumed	Zebra Consumed
Zebra Consumed	1.826	
	(4.93)***	
Topi Consumed	-0.518	0.076
	(0.90)	(0.74)
Buffalo Consumed	0.200	0.28
	(1.31)	(2.07)**
Wildebeest Consumed		0.546
		(4.23)***
Topi Price	553.951	476.906
	(1.82)*	(1.95)*
Zebra Price	230.217	-142.515
	(1.13)	(1.43)
Wildebeest Price	-393.781	157.56
	(1.92)*	(1.53)
Buffalo Price	-467.757	-526.522
	(1.53)	(2.21)**
Household Size	188.994	-51.044
	(2.29)**	(0.74)
Total Income	45.912	12.698
	(2.19)**	(0.48)
Robanda Village	-786.915	-744.552
	(0.05)	(0.11)
Misseke Village	84.056	-177.356
	(0.98)	(2.36)**
Hunting Trips per Year	19.807	-5.024
	(3.69)***	(1.03)
Fish Consumed	-1.956	-4.309
	(1.68)*	(0.91)
Cows Slaughtered	-0.788	-8.242
	(0.02)	(0.22)
Goat/Sheep Slaughtered	-38.696	14.72
	(2.49)**	(1.13)
Chicken Slaughtered	-5.441	5.827
	(0.65)	(1.02)
Education of Female Head	-5.382	-0.824
	(0.44)	(0.08)
Education of Male Head	-0.404	-6.956
	(0.04)	(0.70)
Constant	-709.423	241.725
	(0.85)	(0.34)
Observations	94	94

Table 8: Tobit Regression Results for Wildebeest and Zebra with Livestock

Variable	Coefficient: Wildebeest Consumed	Coefficient: Zebra Consumed
Zebra Consumed	1.825	
	(4.82)***	
Topi Consumed	-0.517	0.068
	(0.88)	(0.65)*
Buffalo Consumed	0.200	0.285
	(1.31)	(2.09)**
Wildebeest Consumed		0.553
		(4.19)***
Topi Price	554.061	468.576
	(1.82)*	(1.90)*
Zebra Price	230.137	-131.729
	(1.13)	(1.26)
Wildebeest Price	-393.73	149.424
	(1.92)**	(1.41)
Buffalo Price	-467.828	-519.518
	(1.53)	(2.17)**
Household Size	189.053	-56.055
	(2.27)**	(0.79)
Total Income	45.970	9.226
	(2.08)**	(0.33)
Livestock	-0.010	0.548
	(0.01)	(0.35)
Robanda Village	-795.828	-728.278
	(0.02)	(0.08)
Misseke Village	84.088	-178.682
	(0.97)	(2.35)**
Hunting Trips per Year	19.806	-4.687
	(3.69)***	(0.94)
Fish Consumed	-1.957	-4.429
	(1.68)*	(0.87)
Cows Slaughtered	-0.669	-10.912
	(0.01)	(0.28)
Goat/Sheep Slaughtered	-38.658	11.862
	(2.30)**	(0.77)
Chicken Slaughtered	-5.417	4.235
	(0.57)	(0.58)
Education of Female Head	-5.404	-0.448
	(0.42)	(0.04)
Education of Male Head	-0.417	-5.642
	(0.04)	(0.52)
Constant	-710.012	262.698
	(0.85)	(0.37)
Observations	94	94

Table 9: Seemingly Unrelated Regression Results

Variable	Coefficient			
	Wildebeest Consumed	Zebra Consumed	Topi Consumed	Buffalo Consumed
Wildebeest Consumed		0.479	0.479	-0.113
		(12.83)***	(12.83)***	(0.99)
Zebra Consumed	1.506		0.706	1.019
	(12.83)***		(1.98)**	(5.54)***
Topi Consumed	0.004	0.057		-0.113
	(0.07)	(1.98)**		(1.91)*
Buffalo Consumed	-0.087	0.249	-0.340	
	(0.99)	(5.54)***	(1.91)*	
Wildebeest Price	-155.352	71.39	34.944	11.410
	(2.68)***	(2.17)**	(0.30)	(0.17)
Zebra Price	24.941	-19.228	60.173	25.917
	(0.47)	(0.64)	(0.57)	(0.43)
Topi Price	50.934	106.836	-750.287	-495.328
	(0.32)	(1.20)	(2.43)**	(2.82)***
Buffalo Price	90.254	-168.855	579.715	510.018
	(0.59)	(1.98)**	(1.93)*	(3.03)***
Household Size	48.002	-29.132	105.29	16.022
	(1.96)*	(2.10)**	(2.18)**	(0.56)
Total Income	11.818	5.362	8.219	2.941
	(1.83)*	(1.13)	(0.49)	(0.31)
Robanda Village	51.650	-27.273	-18.306	3.956
	(1.77)*	(1.68)*	(0.31)	(0.12)
Misseke Village	85.168	-54.118	9.802	50.936
	(2.35)**	(2.69)***	(0.13)	(1.21)
Hunting Trips per Year	15.159	-7.445	-6.186	6.142
	(6.17)***	(4.79)***	(1.06)	(1.84)*
Cows Slaughtered	-4.620	1.943	9.919	-5.737
	(0.35)	(0.26)	(0.37)	(0.38)
Goat/Sheep Slaughtered	-29.677	-14.582	12.398	-9.077
	(4.34)***	(3.62)***	(0.84)	(1.07)
Chicken Slaughtered	-2.507	1.712	-1.930	-1.704
	(0.94)	(1.14)	(0.36)	(0.56)
Fish Consumed	-1.299	-0.651	0.186	-0.513
	(3.28)***	(2.82)***	(0.22)	(1.08)
Education of Female Head	-0.820	5.301	-0.705	1.995
	(0.22)	(0.71)	(0.34)	(0.47)
Education of Male Head	3.153	2.294	-1.667	1.850
	(0.95)	(0.35)	(0.88)	(0.48)
Constant	-401.397	254.487	516.634	-551.849
	(0.92)	(1.04)	(0.60)	(1.12)
Observations	94	94	94	94

Absolute value of z statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 10: Elasticities for Disaggregated Consumption

	Tobit		Tobit with Livestock		SUR			
Variable	Wildebeest Consumed	Zebra Consumed	Wildebeest Consumed	Zebra Consumed	Wildebeest Consumed	Zebra Consumed	Topi Consumed	Buffalo Consumed
Wildebeest Price	-7.791*	5.988	-7.790**	5.679	-3.058***	2.713**	1.204	0.351
Zebra Price	4.555	-5.416	4.554	-5.006	0.491	-0.731	2.073	0.798
Topi Price	10.961*	18.124*	10.963*	17.808*	1.002	4.060	-25.845**	-15.248***
Buffalo Price	-9.255	-20.010**	-9.257	-19.744**	1.776	-6.417***	19.969*	15.700***
Total Income	0.857**	0.483	0.858**	0.351	0.233*	0.204	0.283	0.091
Livestock			-0.0002	0.0208				

* significant at 10%; ** significant at 5%; *** significant at 1%

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Appendix A

Table 1: OLS Regression Results by Animal

	Coefficient			
	Wildebeest	Zebra	Topi	Buffalo
Variable	Consumed	Consumed	Consumed	Consumed
Wildebeest Consumed		0.302	-0.017	0.151
		(2.33)*	(0.12)	(1.81)
Buffalo Consumed	0.154	0.147	-0.184	
	(0.95)	(0.92)	(0.80)	
Zebra Consumed	1.212		0.498	0.577
	(4.82)**		(1.70)	(3.07)**
Topi Consumed	-0.006	0.044		-0.064
	(0.12)	(0.77)		(3.27)**
Buffalo Price	-317.264	-59.649	557.652	370.315
	(1.13)	(0.47)	(0.77)	(3.12)**
Topi Price	438.564	21.267	-725.638	-388.422
	(1.21)	(0.16)	(0.85)	(2.86)**
Zebra Price	52.683	-22.247	51.428	27.852
	(1.73)	(1.25)	(0.64)	(0.83)
Wildebeest Price	-177.21	67.352	35.610	46.527
	(1.41)	(1.68)	(0.34)	(1.02)
Total Income	9.807	1.495	7.472	1.089
	(2.44)*	(0.41)	(0.74)	(0.02)
Robanda Village	20.161	-26.292	-16.917	-19.842
	(0.87)	(1.93)	(0.51)	(0.39)
Misseke Village	34.410	-46.428	5.229	15.262
	(0.91)	(1.67)	(0.09)	(0.28)
Hunting Trips per Year	2.708	0.252	-3.645	-1.156
	(1.13)	(0.39)	(0.96)	(1.14)
Fish Consumed	-0.397	0.038	-0.007	0.080
	(1.56)	(0.41)	(0.04)	(0.78)
Cows Slaughtered	-7.977	-2.107	10.173	-7.099
	(0.73)	(0.49)	(0.62)	(0.63)
Goat/Sheep Slaughtered	-1.130	1.182	7.041	7.061
	(0.14)	(0.23)	(0.75)	(1.43)
Chicken Slaughtered	-6.098	2.750	-0.797	-2.333
	(1.86)	(1.21)	(0.29)	(1.02)
Education of Female Head	0.271	-3.104	3.907	2.472
	(0.06)	(1.14)	(0.84)	(0.71)
Education of Male Head	2.377	0.106	2.667	0.801
	(0.89)	(0.06)	(0.70)	(0.50)
Household Size	66.762	-24.190	103.453	4.049
	(2.05)*	(1.95)	(1.09)	(0.36)
Constant	-242.948	58.420	563.779	-493.562

	(0.65)	(0.16)	(0.78)	(2.59)*
Observations	94	94	94	94
R-squared	0.63	0.65	0.17	0.40

Absolute value of t statistics in parentheses; * significant at 5%; ** significant at 1%

Appendix B

Table 2: OLS Regression Results by Animal with Livestock

	Coefficient			
Variable	Wildebeest Consumed	Zebra Consumed	Topi Consumed	Buffalo Consumed
Wildebeest Consumed		0.300	0.009	0.144
		(2.29)*	(0.06)	(1.79)
Zebra Consumed	1.201		0.494	0.571
	(4.91)**		(1.88)	(3.07)**
Topi Consumed	0.003	0.045		-0.055
	(0.07)	(0.79)		(3.03)**
Buffalo Consumed	0.147	0.146	-0.153	
	(0.93)	(0.91)	(0.80)	
Wildebeest Price	-173.370	67.703	23.342	48.742
	(1.36)	(1.67)	(0.22)	(1.08)
Zebra Price	45.185	-23.257	78.354	21.166
	(1.49)	(1.32)	(0.80)	(0.68)
Topi Price	440.123	21.880	-715.634	-382.314
	(1.20)	(0.17)	(0.86)	(2.91)**
Buffalo Price	-313.761	-59.408	530.489	369.635
	(1.10)	(0.46)	(0.76)	(3.24)**
Hunting Trips	2.709	0.254	-3.582	-1.132
	(1.14)	(0.39)	(0.97)	(1.15)
Total Income	11.048	1.308	12.448	1.101
	(2.06)*	(0.36)	(0.94)	(0.20)
Robanda Village	15.158	-26.974	3.384	-24.181
	(0.67)	(1.94)	(0.10)	(0.46)
Misseke Village	35.371	-46.235	0.263	16.257
	(0.93)	(1.63)	(0.00)	(0.30)
Fish Consumed	-0.425	0.034	0.113	0.053
	(1.75)	(0.35)	(0.62)	(0.48)
Cows Slaughtered	-5.429	-1.750	-0.289	-4.781
	(0.54)	(0.40)	(0.02)	(0.44)
Goat/Sheep Slaughtered	1.280	1.525	-2.923	9.216
	(0.15)	(0.27)	(0.44)	(1.89)
Chicken Slaughtered	-4.524	2.968	-6.959	-0.920
	(1.32)	(1.39)	(0.97)	(0.40)
Education of Female Head	-0.234	-3.174	5.786	2.000
	(0.05)	(1.14)	(0.99)	(0.59)
Education of Male Head	2.029	0.058	3.906	0.493
	(0.77)	(0.04)	(0.88)	(0.30)
Livestock	-0.538	-0.077	2.171	-0.491

	(1.16)	(0.30)	(1.19)	(2.70)**
Household Size	68.192	-23.912	92.021	2.925
	(2.08)*	(1.91)	(1.10)	(0.47)
Constant	-261.637	55.501	623.98	-509.345
	(0.71)	(0.15)	(0.74)	(2.42)*
Observations	94	94	94	94
R-squared	0.63	0.65	0.2	0.41

Absolute value of t statistics in parentheses; * significant at 5%; ** significant at 1%