The Market for Bushmeat: Colobus Satanas on Bioko Island

By
Gail Hearn, Wayne Morra and Andrew J. Buck[‡]

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Abstract

Species conservation is an important issue world wide. The market for monkeys consumed as food on Bioko Island, Equatorial Guinea, is modeled as a bargaining game. Using daily data an empirical density is fit to the price-quantity pairs resulting from exchange between buyers and sellers. The density provides support for the bargaining model. Quantile regressions are also fit to the data. The median quantile indicates buyers have greater bargaining power than sellers. Knowing who has bargaining power aids in the design of policy to reduce bushmeat hunting. Strategic elasticities are also constructed from the quantiles. Given the harvest rate of monkeys and the elasticity estimates, the monkeys of Bioko Island are under considerable pressure.

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I. Introduction

Regular hunting and consuming wild animals, including monkeys, as a food source, known as bushmeat, is common practice in Africa. Bushmeat is the generic term for illegal, commercial trade in wildlife for meat whether that trade was in protected species, in protected areas, or for the express purposes of trade. Apart from the question of legality, commercial hunting of wild animals for food is likely to result in species endangerment or extinction due to the "problem of the commons." Some species of monkeys are presently being hunted at unsustainable rates (Wilkie and Carpenter (1999)). In order to implement policies that will have some effect in the conservation of species it is necessary to have some understanding of the bargaining mechanisms in the bushmeat trade.

The consideration of a single, geographically isolated bushmeat market and species of monkey overcomes some of the reasons for the paucity of empirical evidence on bargaining. Those reasons include the difficulty of finding bargaining data for situations which are similar across multiple instances, the difficulty in observing negotiator characteristics, and the difficulty of measuring the private information of heterogeneous negotiators. The data set used here is quite large (1221 trading days with 2073 carcasses changing hands), is for a homogeneous good,[1] and includes a small number of sellers and a larger

number of buyers that meet repeatedly over the study period. These features of the data preclude buyer or seller characteristics being proxies for product quality, and increase the confidence that the outcome of the negotiation is a result of the asymmetry in the bargaining power of the opponents.

Using daily data on the sales of black colobus (*Colobus satanas*) in Malabo, Equatorial Guinea, kernel densities are fit to price-quantity pairs (Härdle and Kirman (1995)). The price distribution conditional on quantity is bimodal. The higher mode corresponds to a lower price, suggesting that buyers more frequently do better than sellers in the bargaining process. The simple expedience of providing refrigeration in the market may shift bargaining power to sellers, resulting in higher prices and fewer sales. The fact that public power is intermittent may attenuate this effect. On the other hand running back-up generators in addition to being connected to the grid would also help push up monkey prices.

Quantile regression is used to fit an envelope to the economic surplus associated with the trade in monkey bushmeat. The upper most quantile fitted to the data is interpreted as strategic demand[2] and the lowermost quantile is interpreted as strategic supply. The median quantile is found to have a positive slope and lies below the positively sloped OLS regression through the same data. This result corroborates the observation from the empirical density and is interpreted as an

indication that buyers of bushmeat have greater bargaining power than sellers and thereby capture more of the economic surplus.[3]

The interpretation of the quantiles as strategic supply and strategic demand also permits the calculation of elasticities that could be the least upper bound for demand and the greatest lower bound for supply were the market competitive. The price elasticities implied by the quantile results are greater than one, suggesting that population and income growth will shift demand across elastic supply in the neighborhood of current levels of harvest, further aggravating unsustainable harvesting of monkeys on Bioko Island. Similarly, since demand for a particular species is elastic, as hunters become more efficient there will be a large impact on the quantity traded in the market, again aggravating the unsustainable rate of harvest.

Section 2 provides background material on the insignificance of commercial bushmeat hunting in the economy and diet of Bioko Island. The institutional organization of the market for bushmeat, from hunting to point of sale, in Malabo on Bioko Island is also discussed in section 2. The theoretical propositions derived from models of bargaining, other empirical results regarding these propositions, and their relevance to the Malabo bushmeat market are discussed in Section 3. The kernel densities, quantile regression results and discussion of the implied elasticities are presented in section 4. Conclusions and policy recommendations are made in section 5.

II. Background

Researchers from the Universidad Nacional de Guinea Ecuatorial(UNGE) and Arcadia University have alerted the international conservation community to the possibility of extinction of seven monkey species on the island of Bioko, Equatorial Guinea, due to commercial shotgun hunting of bushmeat (Reid et al (2005)). Prior research has presented the same conclusion (Fa et al (1995) and Fa, Juste and Castelo (2000)). In spite of the unsustainable level of harvest, monkey hunting makes a negligible contribution to Equatorial Guinea's economy. Monkey bushmeat from Bioko is an income supplement of about $30 per month[4] for 115 hunters and their families, representing less than 0.01 percent of the country's population. As a share of GDP, the hunting of Bioko's monkeys accounted for 0.003 percent of the nation's economy in 2002. As a share of the country's (or even specific populations') protein intake, monkey meat is similarly unimportant in Malabo.[5] Lastly, monkey meat comprises less than 19 percent of bushmeat revenue in the market in Malabo, Bioko's largest city and center of the island's trade in monkeys and other bushmeat.

The emphasis here is on a particular monkey species in a particular place: the black colobus, *Colobus satanas,* on Bioko Island, Equatorial Guinea, where it may exist as an endemic subspecies (Brandon-Jones and Butynski, cited in Groves, 2001). In addition to its range on Bioko Island, this relatively large monkey with a specialized seed-rich diet is restricted to undisturbed coastal forests in southern Cameroon, mainland Equatorial Guinea, and Gabon. Because its mainland populations are rapidly disappearing to habitat destruction and hunting, black

colobus have been listed among Africa's ten most endangered monkey species (International Union for Conservation of Nature and Natural Resources(IUCN), 1996); because its dietary requirements preclude captive populations, black colobus exist only in the wild. This monkey appears to be more sensitive to habitat disturbance than other pied colobus monkeys. Though a population of as many as 50,000 animals survives in Gabon's Lope Reserve, it is seldom seen in secondary forest,.

Black colobus monkeys were once a common species in Bioko's Pico Basile National Park, one of the island's two nominally protected areas. Even though this species is often described as the least desirable monkey meat (Butynski and Koster, 1994; Colell et al 1994), black colobus, along with the other six monkey species of Bioko Island, have been almost entirely extirpated from Pico Basile; victims of the unsustainable hunting for the nearby Malabo market. Black colobus persist in Bioko's other more remote protected areas, the Gran Caldera de Luba and Southern Highlands Scientific Reserve, and the island could be a refuge for the species.

Since the mid-1990s several factors have combined to create intense pressure on the populations of large forest mammals in Bioko. First, as a result of the discovery and development of offshore oil, local people have more money, driving prices higher and making commercial hunting more profitable. Second, because species reproduce at different rates, some popular bushmeat species (blue duiker[6], *Cephalophus monticola*, and Emin's giant pouched rat, *Cricetomys emini*) are still relatively common

in the forests, while others (Ogilby's duiker, *Cephalophus ogilbyi*, and the monkey species) are increasingly rare. Hunters shoot anything profitable without regard for rarity, taking the rare species almost as "by-catch" when hunting for the more common species. And third, as hunters enter the most remote parts of the island they are now aided by improved roads and many more vehicles traveling from outlying towns[7] to Malabo to deliver the bushmeat and transport hunters.

A team from the Bioko Biodiversity Protection Program[8] (BBPP) interviewed 75 shotgun hunters and 67 trappers in 21 locations around the island in February 2003. According to survey respondents, there were a total of 115 shotgun hunters in the locations studied, which included all the significant hunting camps on the island. Hunters sell between 40 and 60 percent of their take[9] to women (mamás) who resell the monkeys and other bushmeat in Malabo's municipal market[10]. There are around 45 mamás in all, but generally no more than a half-dozen are selling bushmeat at any given time. In some instances the mamás take taxis between the population centers and buy from the hunters along the way. In other instances the hunters send their produce to the mamás via taxi.

Between March 2000 and February 2002, 304 personal interviews were conducted with the buyers of bushmeat in the Malabo market. Twenty-four percent of the respondents were men; 89 percent of the buyers were either Bubi (indigenous) or Fang (from the mainland). Only four percent of respondents selected monkey as their most desired animal.[11] Consuming bushmeat is associated with wealth and status on Bioko. While per capita

gross domestic product for 2001 was estimated to be $2,100, the median income for Fang and Bubi bushmeat buyers was $8,700 and $6,600 respectively.

III. The Market for Bushmeat in Bioko Island

In its essential features the market for bushmeat in Malabo is similar to the Marseille fish market studied by Härdle and Kirman (1995) and the Fulton fish market studied by Graddy (2006) since all transactions are bilateral and no prices are posted. A bargaining model of such markets consists of i=1,2,…,n individuals who buy bushmeat for consumption in a short time interval, say a day. Each of them buys only one monkey and they are ordered according to their reservation prices such that 1 has the highest reservation price and n has the lowest reservation price. Denote the consumers' reservation prices as B_i. The implication for the individuals' elasticity of demand is that $\varepsilon_n \leq \ldots \leq \varepsilon_1$. There is some probability distribution over the different individuals that may come to market to buy a monkey. The probabilities are p_n, p_{n-1},…,p_1.

The seller of monkeys is known as a mamá. On a given day j=1, 2,…,m mamás each bring a monkey for sale in the market. They are ordered so that the reservation price C_1 for monkey 1 is the lowest reservation price and C_m is the highest. The ordering of the elasticities corresponding to the sellers is then $\xi_1 \geq \xi_2 \geq \ldots \geq \xi_m$. In practice the mamás have limited control over the number of monkeys brought to them for sale in the market. Therefore there is some probability distribution over the quantity of monkeys that the mamás are willing and able to sell. The probabilities are q_m, q_{m-1}, …, q_1.

A mamá's reservation price is determined by many factors, including such things as her acquisition costs, the other goods she may have for sale that day, and her other obligations on that day. When a consumer arrives he does not know the true reservation price the mamá has for the displayed monkey. The consumer does know the probability distribution whose support is the set of reservation prices the mamás have for monkeys. Similarly the mamás do not know the reservation prices of customers, but they do know the probability distribution for consumers' reservation prices.

An encounter between a consumer and a mamá is a bargaining problem. The initial step in the bargaining problem can be thought of as two players in a non-cooperative game in which each is playing a mixed strategy. If the consumer with reservation price B_i approaches a mamá and the monkey she has for sale that day is offered at a reservation price such that $C_j > B_i$ then the game does not progress to the bargaining stage. To progress to the bargaining stage the consumer - mamá/monkey pair must be such that $B_i \geq C_j$. The process of matching between mamás and buyers progresses through the day until the market closes or until there are no more monkeys available for sale.[12]

The frequency of one exchange per day is quite common, with monotone reductions in frequency through eight per day as shown in Table 1, along with descriptive statistics for transaction prices. It would be tempting, though incorrect, to interpret the inverse relationship between mean daily price and quantity as indicative of a demand curve (Härdle and Kirman, 1995).

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Insert Table 1 here.

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If arrivals of consumers and arrivals of mamás with $B_i \geq C_j$ both follow independent random processes then the probability of there being exactly one exchange or trade is the probability that one seller (S) arrives and at least one buyer (B) arrives plus the probability that at least one seller arrives and one buyer arrives minus the probability that exactly one buyer and exactly one seller arrive. That is:

$$P(T=1) = P(S=1 \cap B \geq 1) + P(S \geq 1 \cap B = 1) - P(S=1 \cap B=1)$$

Since arrivals of buyers and mamás/monkeys are both Poisson processes[13] independent of one another the parametric representation for the sale of one monkey per day is

$$P(T=1) = \left(\frac{e^{-\lambda_S}\lambda_S}{1!}\right)\left(1 - \frac{e^{-\lambda_B}\lambda_B^0}{0!}\right) + \left(\left(\frac{e^{-\lambda_B}\lambda_B}{1!}\right)\left(1 - \frac{e^{-\lambda_S}\lambda_S^0}{0!}\right)\right) - \left(\frac{e^{-\lambda_B}\lambda_B}{1!}\right)\left(\frac{e^{-\lambda_S}\lambda_S}{1!}\right)$$

More generally, the number of trades taking place per day is given by

$$P(T=t) = \left(\frac{e^{-\lambda_B}\lambda_B^t}{t!}\right)\left[1 - \sum_{j=0}^{t-1}\left(\frac{e^{-\lambda_S}\lambda_S^j}{j!}\right)\right] + \left(\frac{e^{-\lambda_S}\lambda_S^t}{t!}\right)\left[1 - \sum_{j=0}^{t-1}\left(\frac{e^{-\lambda_B}\lambda_B^j}{j!}\right)\right] - \left(\frac{e^{-\lambda_B}\lambda_B^t}{t!}\right)\left(\frac{e^{-\lambda_S}\lambda_S^t}{t!}\right)$$

Where λ_B and λ_S are the rate parameters for buyers and sellers, respectively. Since the random variable T, number of trades per day, is itself a Poisson (Poirier (1995), p. 148), it is possible to estimate its rate parameter. The data set includes no information on consumer - mamá encounters that did not result in a trade. Therefore, the observed

data is from a truncated Poisson and the corresponding probability density function is

$$P(T = t) = \frac{e^{-\lambda}\lambda^{t}}{\left(1 - e^{-\lambda}\right)t!}$$

Maximum likelihood estimates of the rate parameter are presented in table 2 when truncation is ignored and when it is not. Except for dried carcasses, the rate parameters are all greater than one.

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Insert Table 2 here.

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Using the reproduction rates reported by Fa et al (1995) and Slade, Gomulkiewicz and Alexander (1998) an under-estimate of the population necessary to support this harvest rate is about 30,750 animals. Brugiere (1998) and Brugiere and Fleury (2000) estimate that the population density of C. Satanas in an unexploited forest to be .104 animals per hectare. Given the size of Bioko, an over-estimate of the population of C. Satanas on the island is about 15,400 animals. An estimate based on the number of hectares in the protected reserves is only 5930 animals. The current rate of harvest, nearly twice the reproduction rate, is not sustainable.

To reduce the sequential steps of the bargaining model, introduce a variable z=0 if no exchange is possible and z=1 if an exchange is possible. If exchange occurs then at the conclusion of the game there will be a price (p), $zC_j \leq P \leq zB_i$, at which the monkey is sold to the

consumer and p determines the observable division of value between mamá ($P-zC_j$) and consumer (zB_i-P). If no agreement is reached then the payoff to each is zero. Hence the bargaining set is $V = \{(zP-C_j, zB_i-P), (0,0)\}$. As constructed, the payoffs are additive in money and so utility is transferable and the joint value to mamá and buyer is $zB_i + zC_j$.

At this juncture the observed outcomes will depend on the structure of the negotiation game. For example, in a take-it-or-leave-it game the power goes to the proposer. If the consumer is the proposer then she will have a sub-game perfect equilibrium offer equal to the expected value of the sellers' reservation price, $E(C_j)$. If the mamá proposes then she will have a sub-game perfect equilibrium in which she demands a price equal to the expected value of the buyers' reservation price, $E(B_i)$. When buyers and sellers are both homogeneous then there will only be two observed prices; in the observed data one would expect to see a bimodal distribution in price with the modes at B_i and C_j.

When the daily data for black colobus is plotted as a joint empirical density function, as in Figure 1 for adult males and in Figure 2 for adult females, there is evidence of a bimodal distribution. However, the modes are of unequal frequency, suggesting at least some heterogeneity of buyers and sellers. An ultimatum game would generate the observed prices and quantities of Figure 3, a scattergram of average daily price and quantity, if buyers and sellers are heterogeneous.

In a multi-period, alternating offers negotiation game the patient person will come out ahead. When the players are equally patient then the payoff is split equally. Again, heterogeneity of agents is necessary to generate the observed price distribution apparent in Figure 1,2 and 3.

A bargaining set-up with heterogeneous players is quite common in the theoretical literature and provides propositions as to the way in which surplus will be divided between buyer and seller. First, the party whose information about the reservation price of the opponent is least complete will obtain a smaller share of the surplus in negotiations (Ausubel and Doneckere, 1998). Second, the existence of outside options available to one or both parties will affect the distribution of surplus. Even in models in which just one player has options the relationship between the share of surplus and the extent of those other options is not necessarily monotone (Chatterjee and Lee, 1998). More recently, Cuihong, Giampapa and Sycara (2006) show that outside options improve the negotiator's utility significantly. Third, if one of the party's is more impatient then she will obtain a smaller share of the surplus (Ausubel, Cramton and Deneckere, 2002). Lastly, the party with lower disutility from bargaining will obtain a larger share of the surplus (Kennan and Wilson, 1993). The person with a high disutility will be too eager to bring the bargaining to a close in as few rounds as possible.

Empirical evidence regarding the propositions of bargaining theory comes from laboratory experiments and from the field. Morton, Zettelmeyer and

Silva-Risso (2004) survey both literatures. On the basis of their survey, the only proposition for which the laboratory literature is ambiguous is that on impatience. Their paper, based on matched survey and transactions data, is the first comprehensive field based test of bargaining theory. Their results are consistent with the propositions of bargaining theory.

There are some institutional features of the Malabo bushmeat market that tip all four of the bargaining propositions in favor of the buyer of monkey bushmeat. As previously mentioned, the hunters live in primitive hunting camps and are in effect independent contractors that harvest bushmeat opportunistically and send their output to the market on an unscheduled basis. Between the time of a kill and the arrival of the carcass in the market a few days may have passed. In the bush refrigeration is non-existent. Sometimes hunters store the carcass underground if they cannot get it to market in a timely fashion. As a consequence the supply of not so fresh monkeys to the market, which also did not have refrigeration until early 2007, is stochastic, although there are always monkeys for sale when the market is open. The consequence for the mamás is that they cannot carry their stochastic unsold inventory over to future days (see note 10). On any given day there will be several mamás in the market with inventory for sale, but a larger number of buyers. This combination of factors means that the buyers' uncertainty about the mamás' reservation price is certainly less than the converse. Second, buyers always have outside options; they can shop with a different mamá, buy a different type of bushmeat, buy

directly from the hunters when otherwise travelling on the roads to the outlying villages, or postpone their purchase temporally, whereas the mamás outside options are limited by the perishable nature of their product and the fact that there is only one bushmeat market in Malabo. Third, the perishable nature of the product makes the mamás more impatient than buyers; while buyers can postpone a purchase from one day to another or between mamás the same cannot be said for sellers. The mamá cannot wait indefinitely for a customer with a possibly high reservation price. Finally, one would expect the mamás to have the higher transactions costs (disutility) associated with bargaining. The greater the time spent bargaining with a given customer, the less time that can be spent with subsequent customers, thereby increasing the mamás impatience and the probability of accepting a lower price from later customers or being stuck with unsold inventory at the end of the day.[14]

The scatter plot of the data in Figure 3, including the quantiles referred to as supply and demand, shows the division of surplus between buyer and seller. The figure should not be interpreted as the interaction between competitive supply and demand, but is the result of the strategic game outlined here.[15] In their study of the Marseille fish market Härdle and Kirman produced monotone 'demand' functions via the fitting of conditional kernel densities. They assert that their finding is the result of aggregation to the daily level.

IV. Results

The data set used here is the result of an ongoing census commencing in October 1997 of the Malabo bushmeat market conducted by a trained census taker who records the animals arriving for sale at the bushmeat market in Malabo during the morning hours of 8 AM to 12 AM. Each day the species, age (adult or immature), gender, condition of animal (alive, fresh, dried[16]), method of capture (snare, shotgun[17], dog), and price of each bushmeat carcass was recorded. During a total of 2,642 census (or market) days over a period of more than seven years they documented 2,073 black colobus carcasses (16% of all monkeys in the market) traded on 1,221 days.[18] The 'census' data was aggregated to the level of the trading day. An observation consists of the number of black colobus of given age, gender and condition[19] that were traded at a given price. The daily data (n=1,221 days and 2,073 carcasses[20]) are plotted in Figure 3 as (quantity, price) pairs.

Regression quantiles have been fit to the data (Koenker and Bassett (1978), Koenker and Hallock (2001), Bushinsky (1998)). A linear regression model defines the conditional mean of the dependent variable, y, as a linear function of the vector of explanatory variables, x, or $y_t = x_t'\beta + \varepsilon_t$ and $E(y_t \mid x_t') = x_t'\beta$, where ε is an error term. Correspondingly, quantile regression defines the conditional quantiles of the dependent variable as a function of the explanatory variables. Quantile regression describes the entire conditional distribution of the dependent variable given the explanatory variables. The quantile regression representation corresponding to the standard conditional mean representation is

$y_t = x_t'\beta_\theta + \varepsilon_{\theta t}$ and $Q_\theta(y_t \mid x_t) = x_t\beta_\theta$, Where $Q_\theta(y_t \mid x_t')$ denotes the θ^{th} conditional quantile of y_i. θ could be chosen so that the fitted quantile line lies above, say, 25% of the observations on y_i conditional on the explanatory variables. The quantile regression estimator of β_θ is found by solving the problem

$$\min_{\beta} \tfrac{1}{n}\sum_{t=1}^{n}\left[p - \tfrac{1}{2} - \tfrac{1}{2}\operatorname{sgn}\left(y_t - x_t'\beta\right)\right]\left(y_t - x_t'\beta\right).$$

Koenker and D'Orey (1987) and Portnoy and Koenker (1997) describe the linear programming methods for solving the problem.

The downward sloping solid line, interpreted as strategic demand, is the .99 conditional quantile. The upward sloping solid line, interpreted as strategic supply, is the .04 conditional quantile. The horizontal solid line is the median quantile. The dashed line, lying above the median, is an ordinary least squares fit. The coefficients of the fitted lines are reported in Table 3 along with other specifications.[21]

Insert Figure 3 about here.

The scatter of Figure 3 enclosed by the .99 and .04 quantiles[22] represents the economic surplus that can accrue to market participants at corresponding reservations prices.[23] A particular point in the scatter shows the division of surplus between bushmeat consumers and the mamás. That a trade takes place in the interior of the scatter illustrates the relative bargaining power of the participants. Visual inspection of Figure 3 suggests that the capture of surplus is skewed

toward consumers. Table 1 shows the ordering of mean, median and modal price for a carcass by the quantity appearing in the market and confirms the impression that buyers have more bargaining power.[24]

In this simplest interpretation of the data (Figure 3, the 99th quantile is strategic demand and the .04 quantile is strategic supply)[25] and assuming that the equilibrium price was 12,910 Fcfa ($22.55), consumer surplus amounts to 212,938 Fcfa ($372) per day and producer surplus amounts to 23,333 Fcfa ($40.84) per day. Since black colobus make up about 16% of the trade in monkeys, annual producer surplus from all monkeys is about $93,166. Reid et al (2005) report that the amount necessary to compensate hunters for not hunting is about $138,000. Since net operating income accruing to mamás is about the same as that accruing to hunters, the estimated producer surplus from the model corresponds nicely with the detailed accounting figures of Reid et al.

Some alternative specifications[26] of the quantiles were also fit to the data as models two through eight in Table 4.[27] In addition to quantity, the specifications included the price of oil (Poil), the price of beef (Pcow), the price of pork (Phog), a dummy for the age of the monkey (adult or immature), and a dummy for whether the carcass was fresh or dried. Descriptive statistics for these additional variables are in Table 3.

Across all of the specifications quantity has a negative sign in the .99 quantile and a positive sign in the .04 quantile, although the

coefficients are not always statistically significant.[28] Even though there appear to be large numerical differences across the specifications of the demand curve or the supply curve, the changes do not produce great differences in elasticity estimates; see Table 5.

The variable Age is a dummy variable taking the value of one for immature animals. An animal is coded as a immature on the basis of its smaller size. For black colobus there is no obvious physical difference in size for adult males and females, so there is no dummy for gender.[29] For both the .99 and .04 quantiles and all models immatures always trade at a lower price than adults. The variable Dried is a dummy variable taking a value of one to indicate that the carcass has been smoked. Once dried, the gender of the carcass is indeterminate. In both quantiles and across all specifications the effect of drying is to reduce the price of a black colobus.

Other research reports elasticities of demand for bushmeat in the aggregate. Wilkie and Godoy (2001) use household data, but aggregate across all species and do not consider a single geographic market. Reid et al (2005) aggregate to monthly demand and over all species. In both those studies the demand for bushmeat is reported to be inelastic. However, as reported in Table 5, across all of the demand specifications of Table 4 and at all quantities observed to have been traded in Malabo, the point estimate of the own price elasticity of demand, at the variable means, for black colobus is elastic. The first reason for this is algebraic; the quantity coefficients are not especially large in a

statistical sense. The second reason is that there are a small number of mamás operating stalls in the market and economic theory suggests that they should operate in the elastic portion of their demand curve. The third reason is that there are many substitutes for the black colobus available on any given market day.[30]

The supply elasticities implied by the empirical results are also quite large. Because of the relatively flat supply and demand curves of the different models the implied daily equilibrium quantity is quite large. Indeed, it is well above the sustainable take-off rate.[31]

Bushmeat is not the only source of protein for the residents of Bioko Island. Included in their diet are beef, pork, chicken and fish. There is no daily price data for these commodities available for Equatorial Guinea. However, the opportunities for profit taking suggest that whatever their price in Malabo, the prices of these commodities are not likely to drift far from world markets.[32] Since there is no consumer price data available for Equatorial Guinea, models six, seven and eight included the daily closing spot price of beef and hogs on the Chicago Board of Trade. Although the price of beef has a negative sign in the demand quantile equations, it is not significant. However, the short-lived trade interruption with Cameroon in 2000 cut beef imports and was accompanied by a rise in bushmeat consumption, anecdotal evidence that shows there is substitution between the two (Reid et al (2005)). On the other hand, the price of hogs is positive and significant, suggesting that pork is a substitute for bushmeat.

Researchers (Wilkie and Godoy (2001)) have occasionally conjectured that bushmeat might be an inferior good[33] (with negative income elasticity), but in Malabo, the data suggest the reverse. Interpreting the price of oil as a proxy for income, one can conclude that as incomes rise, so does demand; making bushmeat a normal good.

The last column of Table 2 reports the Koenker-Khmaladze test statistics (Koenker and Xiao, 2002) for the location shift and the location-scale shift versions of a quantile regression model. The null of the location shift model is that the individual coefficients do not change across the different quantiles. The null of the location-scale shift model is that the quantile slope coefficients should mimic the behavior of the intercept across the different quantiles. The asymptotic critical value for either test at any reasonable level of significance for models of seven or fewer covariates is under ten. On this basis both null hypotheses are rejected. The practical consequence is that the scatter in Figure 1 cannot be construed as either a probability distribution over a demand curve or probability distribution over a supply curve that has been shifted about in the quantity-price plane.

V. Conclusions

The market for bushmeat in Malabo, Equatorial Guinea, is similar to the Marseille fish market and the Fulton fish market. In each instance the transaction between buyer and seller is the bargaining outcome of a price negotiation. In negotiating price the buyer and seller are

bargaining over the division of economic surplus. Using quantile regression and daily data on the sale of monkey carcasses an envelope around the economic surplus associated with the buying and selling of monkeys is estimated. The quantile regressions provide evidence consistent with the propositions of bargaining theory. Namely, the party with lower disutility of bargaining, greater knowledge of the rivals' reservation price, greater patience, and greater outside options will capture more economic surplus.

In the Malabo bushmeat market it is buyers that appear to have greater bargaining power. Knowing this, we can aim policy towards the buyers and not the sellers. Taxes would obviously reduce buyers' reservation prices. Perhaps subsidizing other food sources would also lower buyers' reservation prices for monkeys.

If buyers have greater bargaining power then agents in the supply chain are getting little of the economic surplus. Therefore suppliers would be willing to switch to other activities in which they could earn more economic surplus. The mamas could switch to other food products easily enough. Hunters are another matter. They live in a rain forest that is ill suited to farming. However, the rain forest is the home to medicinal plants. The market for medicinal plants is international and growing. Furthermore, the area abutting the rain forest is good agricultural land. Prior to independence there were 40,000 Nigerians working on the cacao plantations that are now largely fallow.

The 99th and 4th quantiles fit to the data are interpreted as the strategic demand curve and strategic supply curve, respectively. The elasticity estimates computed from the demand curve and the supply curve underscore the need to curtail both supply and demand for the meat of Bioko's monkeys. A strategy that addresses only supply, by patrolling parks or buying out guns, for example, leaves demand intact. There will be continuing pressure to circumvent obstacles placed between hunters and consumers. Even if supply restrictions raise the cost of monkeys, income is rising so fast as a result of oil development that consumers will be willing to pay higher prices for a similar quantity of meat. By the same token, reducing demand only, through public awareness campaigns, for example, will not change the buying habits of enough people to secure the monkeys' future, and hunters will continue to supply meat without restriction.

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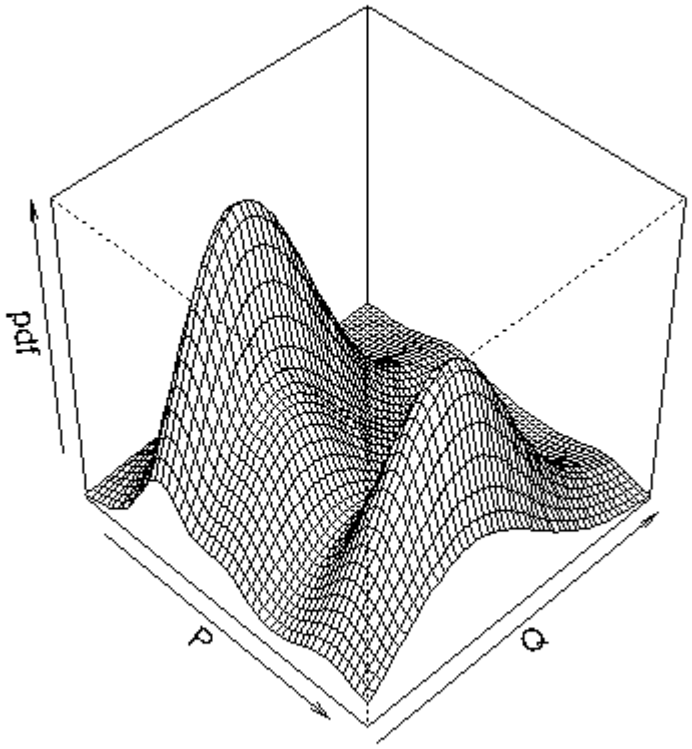
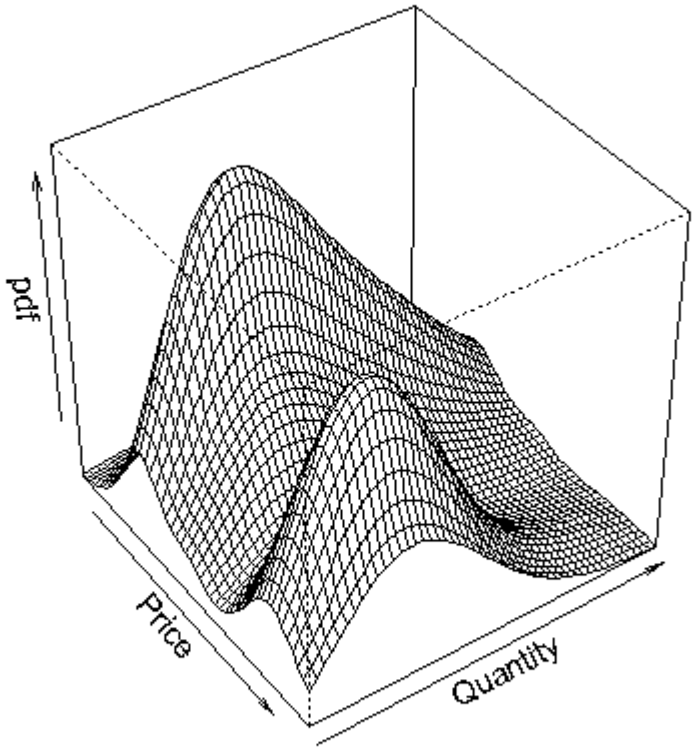
Figure 1
Price-Quantity Joint Density
Black Colobus - Adult Male



Empirical density for Gaussian kernel, bandwidth = 1000, and evaluated at 50 grid points in each direction.

Figure 2
Price-Quantity Joint Density
Black Colobus - Adult Female



Empirical density for Gaussian kernel, bandwidth = 1000, and evaluated at 50 grid points in each direction.

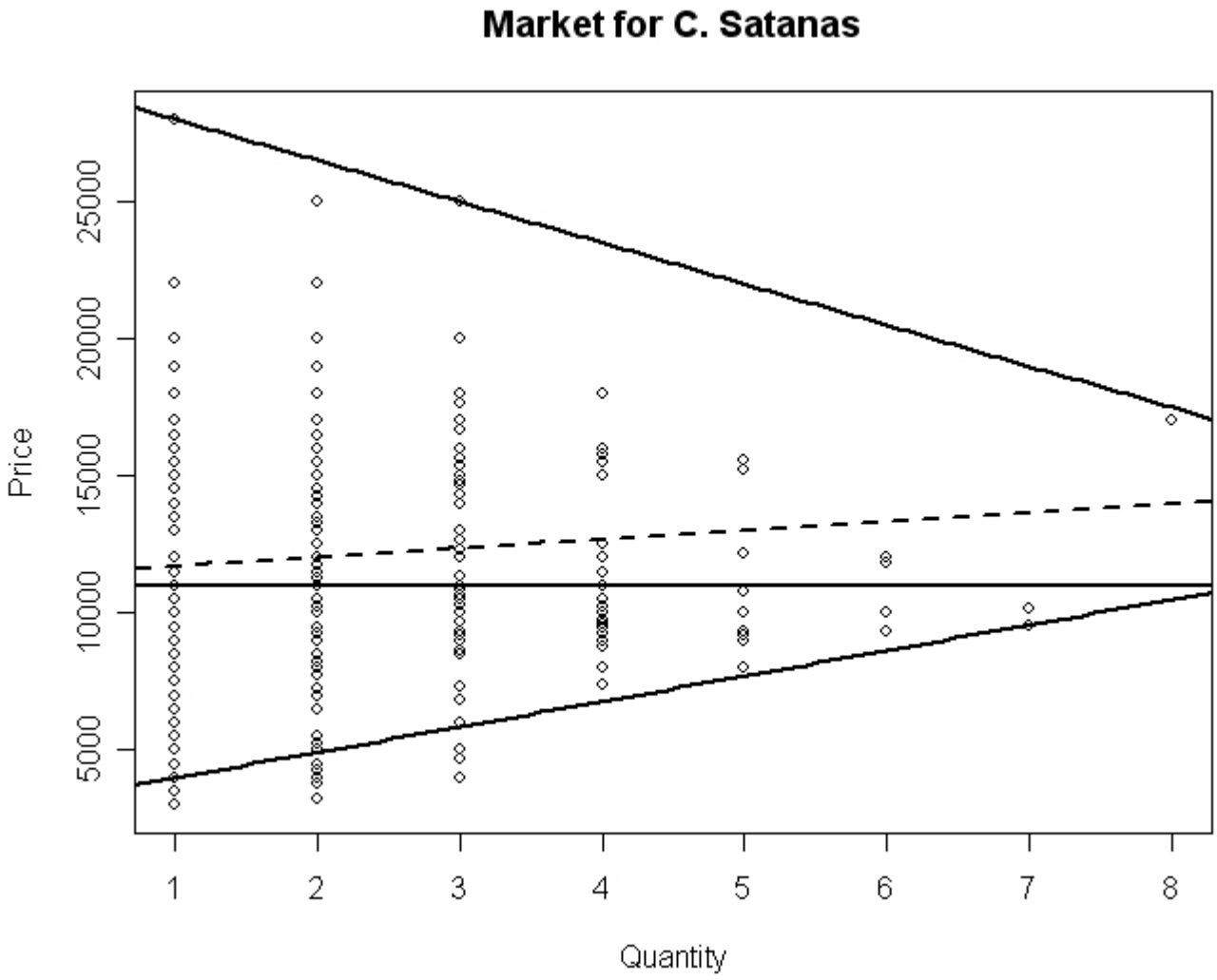

Market for C. Satanas
Price
5000
10000
15000
20000
25000
1
2
3
4
5
6
7
8
Quantity

Figure 3

Table 1
Mean, Median and Mode Price per Carcass (Fcfa) by Quantity per Day

Quantity per Day	Mean	Median	Mode	Days	Carcasses
1	11,415	11,000	10,000	652	652
2	12,674	12,000	10,000	378	756
3	12,336	10,666	10,000	132	396
4	11,452	10,000	10,000	37	148
5	10,863	10,000	10,000	15	75
6	10,791	10916	-	4	24
7	9,857	9,857	-	2	14
8	17,000	17,000	17,000	1	8

Table 2 Carcasses per Day Poisson Parameter Estimates				
Group	Total Carcasses	Days	Poisson	Truncated Possion
All	2073	1221	1.6978	1.3862
Female Immature	216	171	1.2631	1.7438
Female Adult	835	446	1.8722	1.3308
Male Immature	154	129	1.1938	1.8743
Male Adult	797	442	1.8032	1.3602
Dried Immature	13	8	1.6250	.5276
Dried Adult	58	25	2.3200	1.2022

Table 3 Descriptive Statistics n=1221 days		
	Average	Standard Deviation
Price of oil (Poil)	$US 25.77	8.87
Price of beef (Pcow)	$US 71.37	9.85
Price of hogs (Phog)	$US 43.75	13.24
Price of black satanas	Fcfa 11949.21	4254.65
Quantity of black satanas per day	1.70	.95
Age	913 adult	308 immature
Gender*	617 female	571 male
* It is not possible to determine the gender of a smoked or dried carcass. There are 33 such carcasses in the data set.		

Table 4
Quantile Regression Results*
Supply and Demand for Colobus Satanas: Dependent Variable = Price

Model		Intercept	Quantity	Poil	Pcow	Phog	Dried	Age	Joint test
	OLS	11300.7 (45.875)	323.7 (2.535)						
1	Supply	3071.42 (21.03)	146.08 (6.36)						
	Demand	29500.00 (7.75)	-1500.00 (-0.83)						
	Loc	3341.58	3.63						3342.69
	L - S	2064.5	5.25						2066.59
2	Supply	7750.00 (14.62)	250.00 (1.34)				-1250.00 (-2.63)	-4250.00 (-11.60)	
	Demand	29500.00 (8.01)	-1500.00 (-.90)				-7000.00 (-5.01)	-12500.00 (-7.25)	
	Loc	1316.37	2.04				.82	1.40	1320.66
	L - S	467.53	.80				.60	.58	469.78
3	Supply	1717.12 (3.07)	347.57 (1.97)	89.35 (4.43)					
	Demand	5672.21 (3.49)	-378.22 (-1.35)	630.37 (6.92)					
	Loc	1178.31	3.27	1.41					1180.89
	L - S	1388.99	1.71	1.87					1389.75
4	Supply	5569.27 (15.35)	67.32 (.69)	121.95 (14.53)				-4921.95 (-20.75)	
	Demand	7541.33 (3.72)	-722.24 (-1.76)	588.03 (5.28)				-3857.83 (-4.75)	
	Loc	4745.46	.43	8.55				.68	4756.33
	L - S	3825.54	1.20	4.63				.64	3833.31
5	Supply	5621.95 (15.25)	58.54 (.64)	121.95 (9.21)			-2128.05 (-2.81)	-4965.85 (-18.13)	
	Demand	7541.33 (3.82)	-722.24 (-2.04)	588.03 (6.13)			-1910.06 (-1.74)	-3857.83 (-4.86)	
	Loc	3075.53	.69	5.92			1.15	.41	3083.57
	L - S	2393.62	.14	3.54			1.10	.47	2400.15
6	Supply	4871.51 (10.18)	19.96 (.24)	83.56 (4.74)	23.64 (3.08)		-2267.12 (-2.73)	-4477.17 (-16.74)	
	Demand	19697.70 (2.83)	-773.47 (-1.95)	734.64 (3.52)	-255.13 (-1.46)		-1929.86 (-1.52)	-3872.10 (-4.01)	
	Loc	1300.94	.72	5.53	2.65		.92	.54	1313.01
	L - S	3596.80	.41	3.23	1.63		.54	.25	3611.25
7	Supply	5459.14 (4.63)	45.56 (.47)	120.52 (7.71)		6.06 (.21)	-2237.47 (-2.60)	-4970.22 (-16.51)	
	Demand	6976.03 (3.74)	-473.44 (-1.34)	116.83 (1.00)		281.35 (2.92)	-1637.95 (-.99)	-5778.94 (-8.90)	
	Loc	3749.66	.76	1.90		2.73	1.58	1.71	3757.43
	L - S	2969.71	.67	.38		1.28	.46	.19	2075.19
8	Supply	4906.83 (4.80)	21.92 (.27)	84.06 (4.55)	23.80 (2.48)	-1.58 (-.05)	-2247.40 (-2.56)	-4478.08 (-15.18)	
	Demand	17399.43 (3.35)	-380.29 (-.93)	332.15 (2.31)	-222.02 (-1.71)	263.01 (2.71)	-1348.22 (-.76)	-4705.20 (-7.20)	
	Loc	2231.51	.55	2.96	1.22	2.77	.50	.42	2235.65
	L - S	950.93	.53	.13	.73	.21	.60	.49	952.93

* The supply and demand curves are the .04 and .99 quantiles respectively. Bootstrap asymptotic t-statistics based on 200 replications are in parentheses. Khm are the Khmaladze test statistics for no location and no location-scale shift in the conditional distribution.

Table 5
Elasticities*

Model	Elasticity		Q = 1	Q = 4	Q = 7
1	Own Price	Supply	22.03	6.26	4.00
		Demand	-18.67	-3.92	-1.81
8	Own Price	Supply	399.033	95.59	55.81
		Demand	-56.29	-11.77	-5.20
	Income (Price of Oil)		22.77	4.69	2.82
	Substitutes	Beef	-41.60	-10.07	-5.76
		Pork	30.37	6.71	2.59

* The model number refers to the corresponding empirical result in Table 2. The model 1 elasticities are based on the entire sample. The Model 8 elasticities are for fresh male and female, adult black satanas, since these are the predominant carcasses sold in the market. The prices for oil, beef and pork are the means for the observations corresponding to the quantities of satanas carcasses indicated in the column heads.

‡ *Authors:* Professor of Biology, Drexel University, Philadelphia, PA 19104, Phone 215-895-1476, email gwhearn@drexel.edu

Associate Professor of Economics, Arcadia University, Glenside, PA19046, Phone 215-572-2125, email morraw@arcadia.edu

Professor of Economics, Temple University, Philadelphia, PA 19122, Phone 215-646-1332, email buck@temple.edu

[1] The black colobus species is not dimorphic. Animals are sold as whole carcasses and are categorized as either adult or immature based on observed size. There is very little variance in the weight of an adult monkey.

[2] Gustavsen and Rickertsen (2004) used quantile regression in their estimates of demand curves for vegetables in Norway. They do not interpret the slopes of the conditional quantiles as determinative of both supply and demand since all the price coefficients in their study are negative. This is to be expected since at the level of the household the supply of vegetable in the supermarket is perfectly elastic.

[3] The use of quantile regression is now quite common. Koenker and Hallock (2001) and Fitzenberger, Koenker and Machado (2002) offer examples of the many applications in economics.

[4] To add perspective, the Bioko Biodiversity Protection Project pays $800 - $1000 per month for clerical labor and $500 per month for its carcass

census take. The latter wage is comparable to that for janitorial workers at the national university.

[5] Fa, Juste and Castelo (2000) asserts the contrary; namely, bushmeat is an important source of protein and cash for the locals in the Congo Basin. Reid et al (2005) report that as a share of Equatorial Guinea's protein intake, monkey meat is unimportant, capable of fulfilling less than 1 percent of the minimum protein requirement of the urban population. Albrechtson et al (2006) report that for Bioko Island, bushmeat provides a small fraction of the protein needs of the island's residents. Further, 45% of the land under cultivation prior to independence is now fallow and could be brought into production of domesticated animals. deMerode, Homewood and Cowlishaw (2004) report that among those living in extreme poverty in Ghana, bushmeat is an important source of income but is not an important source of food.

[6] Duikers are any one of nineteen small antelope species.

[7] Luba, Riaba and Pico Basile.

[8] A joint initiative of UNGE and Arcadia University.

[9] The remainder of their take is sold on the highway (6%), sold to order (23%), or consumed directly (30%). After firearm and ammunition expenses, hunters are left with Fcfa 16,974(US $30) in monthly income. This is based on interviews with 75 of the 115 shotgun hunters on the island.

[10] Monkeys are sold at an 88 percent markup, on average, leaving market women with average monthly gross profits of approximately Fcfa 620,446 (US$1,087) on sales of 140 monkeys. This calculation is based on

quantities from January 2003 and prices derived from hunter interviews and data gathered in the Malabo market six days a week for all of 2002.

[11] Most preferred was giant pangolin and second was porcupine.

[12] During the sample period there was no refrigeration in the market. It is rare that a mamá is left with a monkey at the end of the day. When it does happen she singes the monkey to increase its shelf life and offers it again the next day at a reduced price since it is no longer regarded as 'fresh.'

[13] The basis for modeling encounters between buyer and mamá can be found in Poirier (1995), p. 90.

[14] The argument could be modeled as an optimal rate of depletion with finite time horizon problem.

[15] Indeed, Becker (1962) showed that downward-sloping demand curves at the market level could be derived from random individual choice behavior subject only to a budget constraint.

[16] Dried is perhaps a misnomer. In fact the carcass is smoked in the hunter's camp over an open fire.

[17] Ninety-nine percent of monkeys are taken by shotgun.

[18] The census takers did not work on Sundays. Also, Black colobus were not available on every day that the market was open.

[19] The gender of a dried carcass is indeterminate. In the statistical results the male-female difference was not important; however a dried carcass sold for significantly less than a fresh carcass.

[20] These numbers differ from the tally earlier in the paragraph for two reasons. First, some data was lost in a house fire in Malabo. Second,

some cases were discarded as a result of coding errors by the data collector.

[21] The 50th quantile results are not included in the table. The intercept is 11,000 Fcfa with a bootstrap t = 42.35. The slope coefficient was numerically zero with a bootstrap t = 0.00.

[22] There are several reasons for this choice of quantiles. First, these quantiles envelope the greatest number of data points in the data sets. Choosing curves to envelope the data could also be done with data envelopment analysis (Banker, Charnes and Cooper (1984)) or stochastic frontier analysis (Aigner, Lovell and Schmidt (1977)). Second, they have slopes consistent with demand and supply curves. Third, although quantile regressions are robust to outliers, the quantiles must go through k of the data points when there are k coefficients being estimated. This has the consequence of making some data points pivotal. That is, other data points could be moved or, as long as they are not moved across the line, without affecting the line, but moving one of those k points will tilt the line. For example, in Figure 1 the 95th quantile would be a horizontal line, as is the median. This is to be expected since the scatter makes plain the change in scale and location conditional on quantity, and is borne out by the Khamaladze Statistics reported in Table 2. Removal of outliers can also have dramatic effects. In figure 1 there is a day when three carcasses were sold for an average price of Fcfa 25,000 and another day on which eight carcasses sold for an average price of Fcfa 17,000. If these two data points are

removed then the strategic demand curve becomes steep enough to intersect strategic supply at seven carcasses per day.

[23] Double oral auctions, or bargaining variants, are used in the classroom to teach the concepts of equilibrium and the role of reservations prices. In these classroom exercises the room is divided into buyers and sellers. Each member of each group is given a reservation price and is then asked to make a deal for the product. The data on deals struck is recorded for each round. At the end of the exercise the instructor puts on the board the demand curve and the supply curve from which the assigned reservation prices were determined. In the same graph the prices at which trades took place across all the rounds of play are plotted. The result is a scatter that is similar to our figure 1. See Holt(1996) or Netusil (2000). In figure 1 of both the cited articles the plotted points are the averages of all trades, and not the scatter of all the individual trades.

[24] The question of whether bargaining power is stable over the entire length of the series is beyond the data set due to the large number of missing days of data; the market was closed or the data collector was not there. Additionally there is no daily consumer price index, or any price index for that matter, with which to deflate the data. In ANOVA tests there is no seasonality in prices. One way ANOVA results in average price being equal in 1997, 1998 and 1999, higher in 2000, equal in 2001, 2002 and 2003, and higher again in 2004. The average price in 2004 is twice that in 1998. In any case, the rising average price would bias the conclusion in favor of the mamás having more bargaining power.

[25] Suppose that in the double oral auction of the previous note an economist is given the P - Q scatter of all the trades and asked to infer the underlying demand curve and supply curve. There is no other available data on the participants in the game or the good being traded. Given the scatter, which would look something like our figure 1, it is quite plain that OLS would not work. A reasonable alternatives would be to use either stochastic frontier analysis, data envelopment analysis or quantile regression and find the curve or curves that envelope the apparent apportionment of the consumer and producer surplus between the participants and argue that the results represent strategic supply and strategic demand.

[26] ARIMA type models were not fit to the daily data. There are many missing days in the data series that do not occur systemically. An entire month of the daily series was lost in a house fire on the island. When aggregated to the monthly level the null hypothesis of no seasonality is not rejected.

[27] In the quantile regressions reported in Table 3 there is, of course, an endogenous variable on the right hand side. We were unable to implement any of the recommended instrumental methods (Lee (2004), Chernozhukov and Hansen (2007), Honore and Hu (2004)) due to a lack of data. Equatorial Guinea is a very poor, underdeveloped country. Other than efforts undertaken by scholars working on funded projects there is virtually no data collection undertaken on a regular basis in the country. For example, Malabo has an international airport and must

track the weather each day. We have been unable to locate even this data.

[28] The Design Matrix Bootstrap Estimator was used, see Buchinksy (1998) for this method and alternatives.

[29] In specifications not reported here, the gender dummy was never significant, as to be expected for the lack of dimorphism.

[30] This begs the question of estimating demand for a single species versus a system of demand curves. As has been pointed out, the lack of data precludes even instrumental variables techniques, let alone trying to estimate a system of demands.

[31] The Bioko Biodiversity Preservation research team conducts censuses of different sections of the island each year. They report, Reid et al (2005), the monkey populations are declining in the heavily hunted areas. Since monkeys are territorial, the conclusion that the take-off rate is too high is inescapable. In addition, in our database the origin of each animal sold in the market is recorded. With the passage of time the number of carcasses coming from some regions of the island has been declining.

[32] Regularly reported data on the prices of fresh and frozen imported beef, chicken, pork and fish that would be necessary to do tests of cointegration between the world price of those commodities and the local price does not exist. However, there are regular flights connecting the island with the rest of the world, the island has refrigeration, and there is a large ex-patriot population on the island to serve the oil industry, all of which would serve to keep local prices from drifting

too far from the world price for too long, apart from transactions costs. Recent data on the prices and sources of origin of bushmeat is suggestive in this regard. Bushmeat prices on the island are now greater than twice those on the mainland, and 'imported' bushmeat now accounts for 22% of revenue and 13% of carcasses seen in the market; up from 2% of carcasses in less than 3 years. Also all beef and pork and most chicken sold in the market and in stores is imported. Some chicken and a little pork are raised domestically. Fish is caught and sold domestically.

[33] On the basis of a panel of 32 households Wilkie and Godoy (2001) report that bushmeat was a necessity for low income households and an inferior good for high income Amerindian households.