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ANALYSIS

The market for bushmeat: *Colobus Satanas* on Bioko Island

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ABSTRACT

Species conservation is an important issue worldwide. The market for monkeys consumed as food on Bioko Island, Equatorial Guinea, is modeled as a bargaining game. The bargaining set-up leads to the conclusion that black colobus are being over-hunted. Using daily data an empirical density is fit to the price–quantity pairs resulting from exchange between buyers and retailers. 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 retailers. Knowing who has bargaining power aids in the design of policy to reduce bushmeat hunting. Strategic elasticities are constructed from the quantiles. Given the harvest rate of monkeys and the elasticity estimates, the monkeys of Bioko Island are under considerable pressure.

1. Introduction

Hunting and consuming of wild animals, including monkeys, as a food source, is common practice in Africa and, apart from the question of legality, may result in species endangerment (Wilkie and Carpenter, 1999) due to the "problem of the commons." Heretofore studies of the market for bushmeat meant to inform public policy have relied on standard economic theory and econometric practice. Wilkie and Godoy (2001) and Wilkie et al. (2005) are prime examples.

The law of one price in economics emerges from perfectly competitive markets in which "the invisible hand" makes the many buyers and many sellers essentially anonymous. Standard econometric simultaneous equations studies of markets implicitly assume them to be perfectly competitive with the result that price–quantity pairs are interpreted as market equilibria thereby permitting construction of estimates of elasticities.

The bushmeat market in Malabo, the subject of this study, is decidedly not perfectly competitive; hence the basic supply and demand model and standard econometric practice are inappropriate. All transactions in the urban Malabo market are the result of direct bargaining between the retailer and the consumer; market participants are players in a non-cooperative game. In a bargaining framework the observed transaction price and quantity must lie in the area between the buyer's reservation price (demand curve) and the seller's reservation price (supply curve) and reveals how the corresponding economic surplus is divided between the two.

A bargaining framework provides a different approach to modeling the bushmeat trade. The bargaining model presented here is implemented empirically using daily data on the sales of carcasses of black colobus (*Colobus satanas*) in Malabo, Equatorial Guinea. The model permits the examination of three issues. First, through parametric estimation of the actual harvest rate we are able to compare actual and sustainable rates of harvest. Second, fitting a kernel probability density to the price–quantity data reveals which party to the trade in monkeys, buyer or retailer, has the greater bargaining power. Third, fitting quantile regressions to the data allows estimation of relevant elasticities.

Based on the empirical results the actual harvest rate is now nearly twice the sustainable rate. The empirical density identifies the consumer as having bargaining power in the market, implying that demand management policies will be more effective than supply management. The elasticity estimates resulting from the quantile regressions are comparable to those reported in other studies and also

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suggest that demand policies will be more effective than supply policies in ameliorating bushmeat consumption.

Section 2 provides background material on commercial bushmeat hunting and the institutional organization of the market on Bioko Island. 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 extent of over-hunting, kernel price density and the relation to bargaining power, quantile regression results, and discussion of the implied elasticities are also presented in Section 3. Conclusions and policy recommendations are made in Section 4.

2. Background

The Bioko Biodiversity Protection Program (BBPP)[3] has alerted the international conservation community to the possibility of extirpation of at least six of the seven monkey species on the island of Bioko, Equatorial Guinea, due to commercial hunting of bushmeat (Reid et al. (2005)). Prior research has presented the same conclusion (Fa et al. (1995) and Fa et al. (2000)). As a share of GDP, the hunting of Bioko's monkeys accounted for 0.003% of the nation's economy in 2002. As a share of the country's total protein intake, monkey meat is similarly unimportant.[4] Lastly, monkey meat comprises about 19% of bushmeat revenue in the market in Malabo, Bioko's largest city and center of the island's trade in bushmeat. Although the bushmeat trade is economically and nutritionally unimportant at the national level it is important to individual market participants and endangers the existence of some species.

The emphasis here is on the black colobus, on Bioko Island, Equatorial Guinea, where it exists as an endangered (IUCN, 1996, 2009) endemic subspecies (Brandon-Jones and Butynski, cited in Groves, 2001). Because its dietary requirements preclude captive populations, black colobus exist only in the wild.

Since the mid-1990s several factors have combined to put pressure on the populations of large forest mammals in Bioko. First, as a result of the development of offshore oil, local inhabitants of Malabo have more income, driving prices higher and making commercial hunting more profitable. Second, because species reproduce at different rates, some popular bushmeat species (blue duiker, *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 in the transport of themselves and their catch by improved roads traveling from outlying towns to Malabo.

Based on surveys conducted by the BBPP between 2000 and 2003 the bushmeat supply chain consisted of 115 shotgun hunters and 67 trappers in 21 locations supplying approximately 45 Malabo retailers, known as mamás. The number of consumers in the Malabo market is undetermined, although both the indigenous Bubi and the Fang, mainland immigrants, consume bushmeat.

The data set used throughout the paper is the result of an ongoing census of the Malabo bushmeat market commencing in October 1997 conducted by a trained census taker who records the animals arriving for sale during the morning hours of 7 AM to 12:30 PM. Each day the species, age (adult or immature), gender, condition of animal (alive, fresh, dried[5]), method of capture (snare, shotgun[6]), and price of each bushmeat carcass was recorded. During a total of 2642 census (or market) days over a period of more than 7 years 2073 black colobus carcasses (16% of all monkeys in the market) were traded on 1221 days.[7] The "census" data is aggregated to the level of the trading day. A daily observation consists of the number and average price of black colobus sold by age, gender and condition.[8] The daily data are plotted in Fig. 3 as (quantity, price) pairs.

3. Modeling the market for bushmeat in Bioko Island

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 publicly posted. Hence a bargaining model is more appropriate than a textbook model of supply and demand. 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,[9] and includes a small number of retailers and a 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.

A bargaining model of the bushmeat market in Malabo consists of $i = 1,2,\ldots,n$ individuals who buy bushmeat for consumption in a short time interval, say a day. By assumption each consumer 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 $p_n, p_{n-1},\ldots,p_1$.

The monkey retailer is known as a mamá. On a given day $j = 1, 2,\ldots, m$ mamás each bring, by assumption, a monkey for sale in the market. They are ordered so that the 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 retailers 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 $q_m, q_{m-1}, \ldots, q_1$.

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 that a particular 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 particular customers, but they do know the probability distribution for consumers' reservation prices.

[3] A joint initiative of Universidad Nacional de Guinea Ecuatorial(UNGE) and Arcadia University.

[4] Fa et al. (2000) assert bushmeat is an important source of protein and cash for the locals in the Congo Basin. Reid et al. (2005) report that monkey meat consumption in Equatorial Guinea fulfills less than 1 percent of the minimum protein requirement of the urban population. Albrechtson et al. (2006) corroborate this finding. deMerode et al. (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.

[5] A dried carcass is one that has been smoked over an open fire in the hunter's camp.

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

[7] The census takers did not work on Sundays and black colobus were not available on every day that the market was open.

[8] The gender of a dried carcass is indeterminate.

[9] 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 little variance in the weight of an adult monkey.

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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	10,916	–	4	24
7	9857	9857	–	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 Poisson
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

An encounter between a consumer and a mamá is a bargaining problem. The initial step in the bargaining problem is a non-cooperative game in which the players employ 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 encounter 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.[10]

Table 1 provides descriptive statistics for transaction prices and number of carcasses traded per day. In the table there appears to be an inverse relationship between price and quantity. 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).

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 (Poirier (1997), p. 90) independent of one another the parametric representation for the sale of one monkey per day is

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

[10] 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 extend its shelf life and offers it again the next day at a reduced price since it is no longer regarded as 'fresh.'

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, determined by the probabilities over the reservation prices (p_i, q_j). Since the random variable T, number of trades per day, is itself a Poisson (Poirier (1997), p. 148), it is possible to estimate its rate parameter. The data set only contains transactions that result in a trade between a consumer and a mamá. Because we don't observe instances in which the buyer and mamá fail to arrive at an agreement, the observed data is from a truncated Poisson and the truncation corrected probability density function is

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

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.

Using the reproduction rates reported by Fa et al. (1995) and Slade et al. (1998) an under-estimate of the population necessary to support this harvest rate is about 30,750 animals. Brugière (1998) and Brugiere and Fleury (2000) estimate that the population density of black colobus in an unexploited forest to be .104 animals/ha. Given the size of Bioko, an over-estimate of the population of black colobus on the island is about 15,400 animals. An estimate based on the number of hectares in the protected reserves is only 5930 animals. Given the carrying capacity of the island, the current rate of harvest (Table 2), is nearly twice the reproduction rate.

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

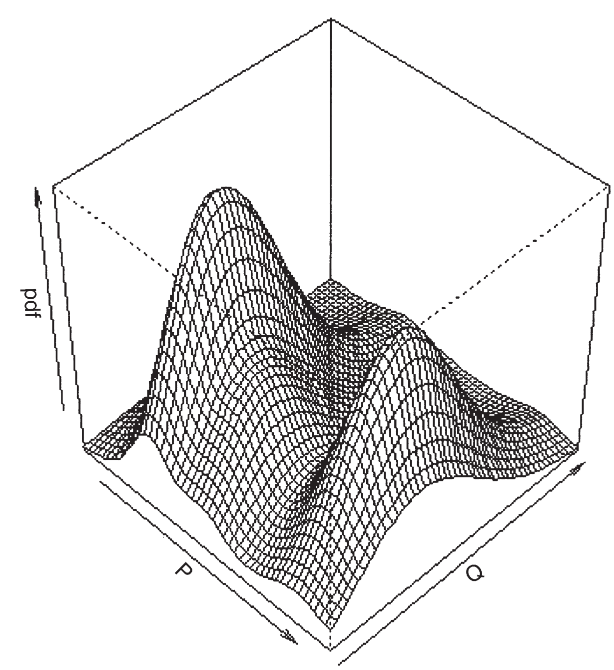

Fig. 1. Price–quantity joint density black colobus–adult male.

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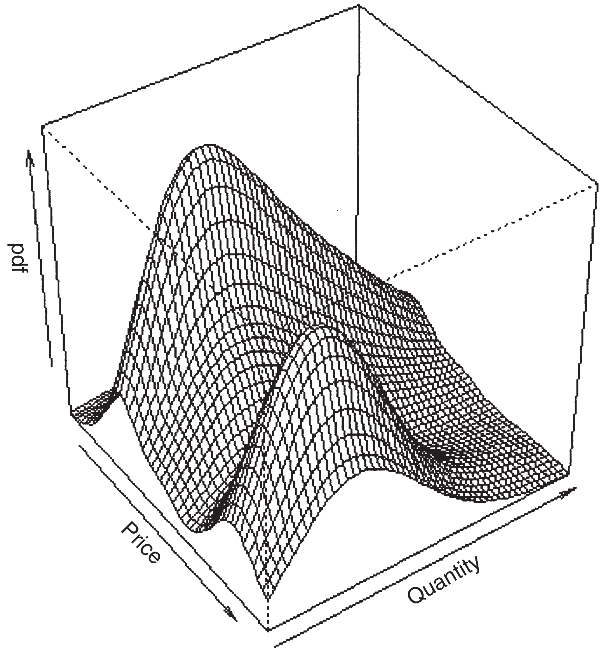

Fig. 2. Price–quantity joint density black colobus–adult female.

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 $zB_i + zC_j$.

If the negotiation and consequent bargaining set is a one period take-it-or-leave-it game then the power goes to the proposer. If the consumer is the proposer then he will have a sub-game perfect equilibrium offer equal to the expected value of the sellers' reservation price, $E(C_j)$; there will be a single mode in the empirical probability density for price. 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, $E(B_i)$; the empirical density will also be unimodal. 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 $E(B_i)$ and $E(C_j)$.

When the daily data for black colobus is plotted as a joint empirical density function, as in Fig. 1 for adult males and in Fig. 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 retailers. The higher mode corresponds to a lower price, suggesting that buyers more frequently do better than retailers in the bargaining process.

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

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 opponent's reservation price is least complete will obtain a smaller share of the surplus. (Ausubel and Deneckere, 1998). Second, the existence of players' outside options will affect the distribution of surplus. Building on Chatterjee and Lee (1998), Cuihong et al. (2006) show that outside options improve the negotiator's payoff significantly. Third, if one party is more impatient then she will obtain a smaller share of the surplus (Ausubel et al., 2002). Lastly, the party with lower disutility from bargaining will obtain a larger share of the surplus (Kennan and Wilson, 1993).

Institutional features of the Malabo bushmeat market tip all four of the bargaining propositions in favor of the buyer of a monkey. 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. Several days may pass between the time of a kill and the arrival of the carcass in the market. In

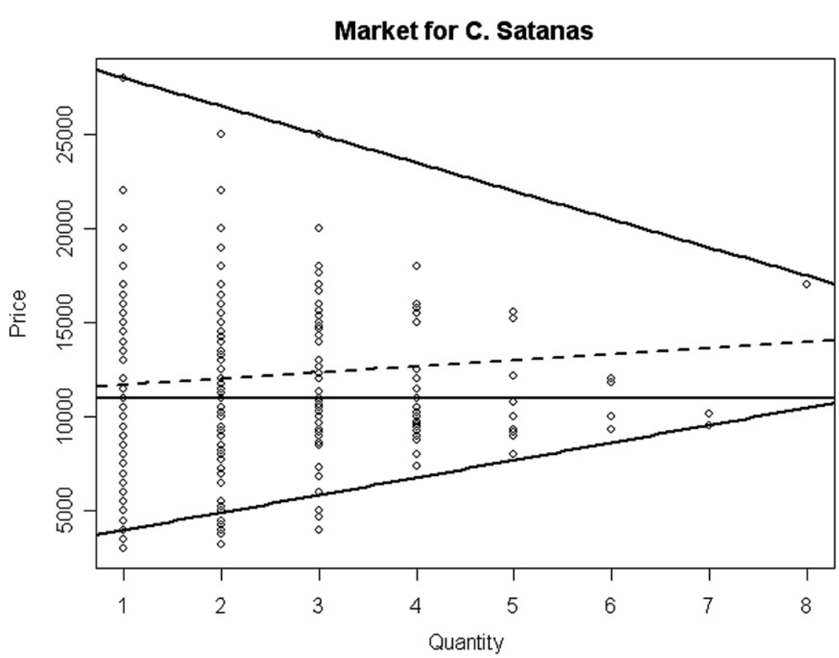

Fig. 3. Strategic Demand and Strategic Supply.

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the bush refrigeration is non-existent.[11] As a consequence the supply of not so fresh monkeys to the market is stochastic. There also is no refrigeration in the market. The consequence for the mamás is that they cannot carry their stochastic unsold inventory over to future days. 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, or postpone their purchase inter-temporaly, 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, bushmeat perishability makes the mamás more impatient than buyers; while buyers can shift a purchase from one day to another or between mamás the same cannot be said for retailers. The mamá cannot wait indefinitely for a customer with a possibly high reservation price. Finally, 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 or being stuck with unsold inventory at the end of the day.

Given the heterogeneity of consumers and mamás, the imbalance in bargaining power between them, and the unique character of the data, quantile regression permits modeling reservation prices of buyers and sellers.[12] An early example of the use of regression quantiles to model reservation prices is Gustavsen and Rickertsen (2004).

Regression quantiles have been fit to the data (Koenker and Bassett (1978), Koenker and Hallock (2001), Buchinsky (1998)). An ordinary least squares model defines the conditional mean of the dependent variable (y) as a function of the vector of explanatory variables (x) or $y_t = x_t'\beta + \varepsilon_t$ and $E(y_t|x_t') = x_t'\beta$, where ε is an error term. Correspondingly, quantile regression defines, say, the conditional median of the dependent variable as a function of the explanatory variables. The regression quantiles can describe the entire conditional distribution of the dependent variable. The quantile regression corresponding to the standard conditional mean representation is $y_t = x_t'\beta_\theta + \varepsilon_{\theta t}$ and $Q_\theta(y_t|x_t) = x_t\beta_\theta$, where $Q_\theta(y_t|x_t')$ 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 linear programming problem (Koenker and D'Orey (1987) and Portnoy and Koenker (1997)):

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

A feature of the solution (parameter estimates) is that the fitted quantile must go through a number of observations equal to the number of parameters being estimated. That is, if the model has an intercept and only one regressor then any particular quantile goes through two observations in the x–y plane. The particular points are chosen by the estimation routine so that, say, 75% of the data lies below the estimated line, conditional on a value for x. Although quantiles are robust to outliers in a way that ordinary least squares is not, the slope of the quantile can still be sensitive to artifacts in the data.

Different specifications of the quantile model are reported in Table 5). The simplest specification has price as the dependent variable and only quantity on the right hand side. The .99, .50 and .04 quantiles were fit to this as well as more complex specifications. The data scattergram and the three quantiles are shown in Fig. 3. The .99 and .04 quantiles were chosen for two reasons. First, they envelope the observed bargaining outcomes in a fashion consistent with the way a demand curve and a supply curve would envelope the price and quantity pairs that could be observed in a bargaining game paradigm. The second reason is a consequence of the estimator being the flattest line consistent with cutting off a given percent of observations on the dependent variable conditional on the independent variable(s). The uppermost quantile is downward sloping, but as the conditional percentile is reduced the line flattens out until it has zero slope at the condition median, the .5 quantile. The .04 quantile is upward sloping, but the higher quantiles flatten out until the median is reached.[13]

In Fig. 3 the downward sloping solid line is interpreted as strategic demand, reflecting the reservations prices of the buyers in the bargaining model. The upward sloping solid line is interpreted as strategic supply, reflecting the reservation prices of retailers. The horizontal solid line is the median quantile. The dashed line, lying above the median, is an ordinary least squares fit. The capture of surplus is skewed toward consumers. This result corroborates the observation from the empirical density and is interpreted as an indication that buyers of bushmeat have greater bargaining power[14] than retailers and thereby capture more of the economic surplus that results from any mutually beneficial trade. 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. 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. The demand elasticities implied by the quantile results are greater than 1 (Table 4).

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
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.

[11] Sometimes hunters store the carcass underground if they cannot get it to market in a timely fashion.

[12] Koenker and Hallock (2001) and Fitzenberger, Koenker and Machado (2002) offer examples of the many applications of quantile regression in economics.

[13] The regression quantiles below .04 also flatten out, but this is an artifact of the; both price an quantity are approaching their lower bound for the lowest quantiles so the line must flatten out.

[14] 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. 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, the reverse of what we find.

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Table 5
Quantile regression results* supply and demand for *Colobus satanas*: dependent variable = price.

Model		Intercept	Quantity	*P*oil	*P*cow	*P*hog	Dried	Age	Joint test
1	OLS	11300.7	323.7						
		(45.875)	(2.535)						
	Supply	3071.42	146.08						
		(21.03)	(6.36)						
	Demand	29500.00	−1500.00						
		(7.75)	(−0.83)						
	Loc	3341.58	3.63						3342.69
	L–S	2064.5	5.25						2066.59
2	Supply	7750.00	250.00				−1250.00	−4250.00	
		(14.62)	(1.34)				(−2.63)	(−11.60)	
	Demand	29500.00	−1500.00				−7000.00	−12500.00	
		(8.01)	(−.90)				(−5.01)	(−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	347.57	89.35					
		(3.07)	(1.97)	(4.43)					
	Demand	5672.21	−378.22	630.37					
		(3.49)	(−1.35)	(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	67.32	121.95				−4921.95	
		(15.35)	(.69)	(14.53)				(−20.75)	
	Demand	7541.33	−722.24	588.03				−3857.83	
		(3.72)	(−1.76)	(5.28)				(−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	58.54	121.95			−2128.05	−4965.85	
		(15.25)	(.64)	(9.21)			(−2.81)	(−18.13)	
	Demand	7541.33	−722.24	588.03			−1910.06	−3857.83	
		(3.82)	(−2.04)	(6.13)			(−1.74)	(−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	19.96	83.56	23.64		−2267.12	−4477.17	
		(10.18)	(.24)	(4.74)	(3.08)		(−2.73)	(−16.74)	
	Demand	19697.70	−773.47	734.64	−255.13		−1929.86	−3872.10	
		(2.83)	(−1.95)	(3.52)	(−1.46)		(−1.52)	(−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	45.56	120.52		6.06	−2237.47	−4970.22	
		(4.63)	(.47)	(7.71)		(.21)	(−2.60)	(−16.51)	
	Demand	6976.03	−473.44	116.83		281.35	−1637.95	−5778.94	
		(3.74)	(−1.34)	(1.00)		(2.92)	(−.99)	(−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	21.92	84.06	23.80	−1.58	−2247.40	−4478.08	
		(4.80)	(.27)	(4.55)	(2.48)	(−.05)	(−2.56)	(−15.18)	
	Demand	17399.43	−380.29	332.15	−222.02	263.01	−1348.22	−4705.20	
		(3.35)	(−.93)	(2.31)	(−1.71)	(2.71)	(−.76)	(−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.

Alternative specifications[15] of the quantiles were also fit to the data as models two through eight in Table 5.[16] In addition to quantity, the specifications included the price of oil (*P*oil), the price of beef (*P*cow), the price of pork (*P*hog), 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.[17] 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 4.

The Age dummy variable takes the value of one for immature animals. An animal is coded as 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.[18] For all models immatures always trade at a lower price than adults. The Dried dummy variable takes a value of one to indicate that the carcass has been smoked. Once dried, the gender of the carcass is indeterminate. 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 they aggregate across 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

[15] ARIMA type models were not fit to the daily data. There are many missing days in the data series that do not occur systematically. An entire month of the daily series was lost in a house fire on the island.

[16] In the quantile regressions reported in Table 5 there is an endogenous variable on the right hand side. Instrumental methods could not be implemented (Lee (2004), Chernozhukov and Hansen (2007), Honore and Hu (2004)) due to a lack of data collection in Equatorial Guinea.

[17] The Design Matrix Bootstrap Estimator was used; see Buchinsky (1998).

[18] In specifications not reported here, the gender dummy was never significant.

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be inelastic. However, as reported in Table 4, across all of the demand specifications of Table 5 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 economic theory suggests that the mamás should operate in the elastic portion of the demand curve. The third reason is that there are many substitutes for the black colobus available on any given market day.[19]

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 and is well above the sustainable take-off rate.[20]

Bushmeat is not the only source of protein for the residents of Bioko Island. Beef, pork, chicken and fish are readily available in supermarkets in Malabo. 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.[21] 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, suggesting there is substitution between the two (Reid et al. (2005)). On the other hand, the price of hogs coefficient is positive and significant, suggesting that pork is a substitute for bushmeat.

Wilkie and Godoy (2001) have conjectured that bushmeat is an inferior good for high income households[22] (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 5 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 Fig. 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.

4. Conclusions

The observed transactions between buyers and retailers in the market for bushmeat in Malabo, Equatorial Guinea, are the bargaining outcome of a price negotiation. The buyer and retailer are bargaining over the division of economic surplus between their respective reservation prices. Using daily data on bushmeat sales, an empirical joint probability density function supports the proposition of asymmetry in bargaining power between buyers and retailers. Using the same data, quantile regression provides an envelope around the economic surplus associated with the buying and selling of monkeys. 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, public policy can be aimed more towards buyers than retailers. Taxes would obviously reduce buyers' reservation prices and thereby reducing quantity traded. 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 a smaller portion of the economic surplus. Therefore suppliers would be willing to switch to other activities in which they could earn more economic surplus. The mamás could switch to other food products easily enough. Hunters are another matter.

The simple expedience of providing refrigeration in the market may shift bargaining power to retailers, resulting in higher prices and fewer sales. The shift in bargaining power results from retailers having the ability to store their inventory from one day to the next; they can afford to wait for a higher offer price. In addition, with storage opportunities, the retailers can exert pressure on hunters to limit the rate of harvest. The fact that electricity 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.

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 quantiles 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.

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. This suggests that population and income growth will shift demand across an 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. 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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[19] The lack of data precludes trying to estimate a system of demands.

[20] The annual BBPP censuses of different sections of the island report that monkey populations are declining in the heavily hunted areas. See Reid et al. (2005).

[21] Regularly reported data on the prices of fresh and frozen imported beef, chicken, pork and fish 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. Data on the prices and sources of origin of bushmeat show that prices on the island are now more 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.

[22] Using 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.

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