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Valuation of cattle attributes in the Malian humid and sub-humid zones and implications for a sustainable management of endemic ruminant livestock

Abstract

The preservation for future use of endemic ruminant livestock (ERL) depends on how these breeds are perceived by smallholders in relation to their Sahelian counterparts with a larger frame. These indigenous livestock breeds have unique genetic traits that are important to smallholders' livelihood. In Mali, the dwindling number of purebred Ndama cattle, a breed known for its tolerance to trypanosomosis, is cause for concern to many stakeholders. Markets are the institutions through which the appropriate incentives to rear endemic ruminant livestock are identified. A revealed preference approach was conceptualized and applied to data collected on observed transactions in randomly selected cattle markets in the Malian humid and sub-humid zones. The results indicate that the body condition, the agro-ecological origin, and the category of the transacted animal are the three most important attributes. The importance of Body Condition illustrated by the high premium rates paid for excellent body condition combined with the relatively low discount rates for the Ndama and Crossbred breed confirms that if all maintenance costs are accounted for, Ndama cattle with excellent body condition could be as profitable as Zebu. The findings have production, marketing, and animal genetic resource management implications. The results would enable Ndama producers and traders to make more informed production and marketing decisions because they would be better informed about how the attributes of cattle they put on the market are rewarded or penalized. More importantly, while crossbreeding may lead to higher prices, selection within the breed and fattening are the best avenues that could lead to better prospects for Ndama producers. They lead to better prices while protecting the breed for future use.

Keywords: endemic ruminant livestock, attributes, implicit prices, preservation, sustainable use.
JEL Classification: Q12, Q50, Q56.

Introduction

African livestock production systems are at a crossroads. They are undergoing significant change as a result of both supply and demand-side shocks. On the demand side, the combination of higher income, population growth, and market liberalization is leading to increased demand for animal sourced food (Delgado et al., 1999). The changing demand for differentiated livestock products is inducing changes in the animal product procurement systems, with imports playing a major role. This has rendered small producers more vulnerable to external shocks. On the supply side, the logic of traditional pastoral systems based on mobility first stated by Toure (1986) is still debated today, following repeated climatic disasters. One of the major adjustments is a growing advocacy for the use of species with short production cycle, particularly poultry and pigs to respond to the growing demand of animal sourced food (Delgado et al., 2001).

Satisfying consumer needs, especially in urban populations, for affordable food, including animal products has always been a major preoccupation for most African governments (Bates, 1981). The approaches towards meeting these needs have traditionally been focused on productivity enhancement (Ly, Pica-Ciamarra and Otte, 2010). The productivity enhancement approach, however, neglects the contribution of livestock to maintaining ecological and genetic diversity, supplying draught power and nutrients for crop production, and providing insurance against unforeseen events (Simianer, 2000). These multiple functions of livestock are better fulfilled by breeds better adapted to the harsh local conditions (Wollny, 2003). This is particularly true for the Ndama cattle, a breed with a small frame, endemic to the humid and sub-humid zones of West and Central Africa. Farming systems in these zones are classified as agro-pastoral, mixed crop-livestock, and peri-urban; all of which are characterized by varying degrees of crop-livestock integration. These breeds are tolerant to heat, and are resistant to a variety of diseases such as dermatophilosis, heartwarter, and strongyloidisis (Agyman, 2005). More importantly, these indigenous livestock breeds have developed a tolerance against trypanosomosis, a parasitic disease transmitted by the tsetse flies that render livestock rearing very challenging in areas with significant biomass availability. These adaptive traits have enabled the Ndama to remain productive in tsetse infested areas where their Sahelian counterparts would not survive (Shaw and Hoste, 1987) or would require heavy intakes of trypanocides, which increase their maintenance costs.

Hence, a breeding strategy that targets few marketable attributes understates the benefits of keeping

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local breeds by failing to fully account for the multiple functions of livestock in smallholder crop livestock system and the centrality of local breeds in that paradigm (Ayalew, 2000). Anderson (2003) and Wollny (2003) further reflected on the counter-productivity of such a strategy, which they said, has far-reaching consequences because of the complex interactions between animal genetic resources (AnGR) and poverty. According to Ayalew, the importance of local breeds is in fact discounted in relation to what is widely presumed to be gained from rearing exotic breeds. The major threats these breeds are currently facing have production, environmental, and ecological implications.

The prevalence of naive crossbreeding schemes by livestock producers is also a major contributing factor to the genetic erosion of farm animal (Mhlanga, 2002; Simianer, 2000). In Mali, there is a well-founded concern that uncontrolled crossbreeding with the Zebu, a breed of the Sahelian (arid) zone purportedly of superior attributes because of its larger frame, would accelerate the genetic dilution of the Ndama, ultimately leading to its demise. Malian cattle population is estimated at 7 million heads with the Ndama breed accounting for 14% of total stock (FAO-Ministry of Agriculture, 2005). This is lower than its 1985 share estimated at 16% of total stock (Shaw and Host, 1987). In reality, the extent to which the current Ndama population is affected is not known; but some studies have found the number of purebred Ndama lower than previously thought, explaining some farmers' difficulties in finding herd replacements.

It is clear that new intervention strategies are needed to better manage these AnGR at risk. The question is how to reconcile the two seemingly contradictory goals, namely the private profit maximizing motive of producers and the preservation of biodiversity, which is essentially a public good. Resolution clearly requires prioritization and identification of many possible options. In turn, design of short and medium term interventions obviate the need for a rigorous process centered on the policy and legal frameworks that govern the access to, use of, these resources. The stakeholders include the local communities as the owners of these resources and whose well-being is at stake. The assets at stake include the existing and endangered AnGR such as ERL threatened by genetic dilution, and the institutions involved include the markets, through which AnGR are exchanged.

With respect to market, the key issue is to identify the incentives for livestock producers to keep Ndama. A strong incentive base for Ndama keepers could be achieved by improving market agents and producers' understanding of how Ndama traits are valued in the marketplace. Hence, this study seeks to (1) assess how these attributes are valued across the various categories of buyers procuring live animals for breeding, resale, or slaughter; (2) gain a firmer understanding of the relative importance of each of these attributes; and (3) identify marketing opportunities for Ndama producers in Mali based on the premiums and discounts each attribute commands in the marketplace. A revealed preference approach was applied to data collected on observed transactions throughout randomly selected cattle markets in the Malian humid and sub-humid zones. The rest of the report is organized as follows. The first section focuses on the conceptual analysis and model derivation. The second deals with sampling strategy. The third focuses on the descriptive analysis, hedonic estimation results, and the stochastic simulation results. The last section focuses on concluding comments.

1. Conceptual analysis and model derivation

Buyers of live cattle are not interested in cattle as physical goods; rather, they are basing their decision on attributes such as Coat Color, Agro-ecological Origin, Body Condition, Breed, and Category, among others. The attributes provide the utility buyers gain for satisfactorily concluding a transaction (Lancaster, 1966). Following Harrison and Rubinfeld (1978), a utility maximization based on attributes was stated as:

Maximize $U(x,z)$

subject to $y = x + p(z) + c$

with x and $z \geq 0$,

where z is the vector of attributes, x is the expenditure on all other goods, y is the money income, c are the remaining costs, and p (z) is the hedonic price function that maps the vector of cattle attributes to a corresponding price level at each attribute. The first order condition of the utility maximization process subject to money income constraint is obtained by solving the Lagrangean equation to derive the marginal implicit price of each attribute, z_i, in the vector of z. The optimal solution can be expressed as follows:

$$w_{z_i}(z) = U'(z)/U'(x) = \partial p(z)/\partial(z_i).$$

The relative importance of any attribute within the vector of attributes changes depends on the buyer's profile and the intended use of the purchased cattle. For instance a butcher may not care about coat color while an ordinary consumer buying for familial ceremony may factor coat color in their purchasing decision. This would be reflected on the marginal

implicit price they place on a particular coat color, depending on whether they like it, dislike it, or are simply indifferent about it. Moreover, a butcher with a high commercial capacity or catering for the high income segment of the population may target animal with an excellent body condition while another targeting the lower end of the consuming public may look at animal with a poor body condition such as culled cows. Thus, an accurate account of the contribution of each attribute to the formation of price may require controlling for these factors.

The proposed model is based on the utility maximization process laid out above whereby the hedonic function that links cattle price and cattle attributes was elucidated. Rosen (1974) and Freeman III (1974) popularized the use of hedonic model to estimate marginal willingness to pay for attributes such as environmental quality. This is based on the revealed preference approach and is a theoretically sound way to evaluate consumer valuation of attributes. Jabbar (1998) applied the approach to study buyers' valuation of small ruminants' attributes in Nigeria. There are other methods such as those based on stated preference approach (Girma et al., 2011). Stated preference approach has been effective when dealing with preference for non marketed attributes; however, they are prone to erroneous results because of hypothetical biases and cognitive limitations of respondent to handle numerous product profiles and require a test for preference consistency to detect any biases in the parameter estimates (Scarpa et al., 2003).

Our approach for this study follows Gollin and Evenson's (2003) recommendations to combine hedonic methods with simulation techniques using observed market transactions, attributes of the transacted animals collected by livestock technicians, socioeconomic information on buyers and sellers, and market characteristics. The hedonic model can be formally presented as follows:

$$Log\left[p\left(z\right)\right] = X_1\alpha + X_2\beta + \varepsilon \text{ with } \varepsilon \sim N\left(0, \sigma^2\right).$$

The matrix X_1 contains the control variables, X_2 are the attributes of the purchased cattle, the parameter vector ß quantifies the difference in percent between the marginal implicit prices of the reference level relative to that of specified level, and α measures the marginal impacts of market and buyer's profile on price. The error term ε is assumed to have mean zero and be homoskedastic (with constant variance σ^2). To ascertain efficiency in the standard error estimates, we applied the White (1980) heteroskedastic consistent covariance matrix in all estimations. The explanatory variables are drawn from Table 1 (Appendix) where needed dummy variables are constructed and the estimation implemented by Ordinary Least Squares.

A Monte Carlo simulation was conducted using the parameters of the probability density function of the estimated hedonic price equation in each category to generate 10,000 simulated base prices and premiums/discounts for each attribute across various market agents. The simulated base prices and premiums/discounts were used to produce estimates of parameter of central tendencies and dispersion for the premiums and discounts. The stochastic averages obtained through this procedure are more robust than their deterministic counterparts (Westhoff et al., 2006) and used to predict the prices of any cattle profiles holding market characteristics and demographic information constant. The stochastic averages with the lower and upper quintiles between brackets are presented along with the graphs of the simulated distribution of the key output variables.

2. Variable description and data considerations

Table 2 (Appendix) displays the variables used in the hedonic model. The specified variables indicate that terminal market is the reference dummy for market type, experienced market agent for professional experience, illiterate for education, etc. Thus, the reference profile is a white zebu bull of poor body condition reported to have originated from the humid and sub-humid zone. Its price is referred to as base price. It is determined using the estimated regression results. The marginal implicit price of an attribute level is the difference between the base price and the predicted price obtained by changing the attribute level one at a time. It is a premium, if positive, and a discount, if negative. The premiums or discounts represent the amount of money the market is rewarding or penalizing an attribute level. Their magnitudes depend on the intended use of the purchased stock, the profile of the buyer, and the market where the purchase is made. Thus, it is a marketing indicator that could help refine marketing strategies by informing supply side participants about the most remunerative attributes or combination of attributes. For this reason, the specified model will be estimated over the entire sample and across market agents to generate a more accurate account of the various premiums and discounts of cattle attributes.

A survey of live animals' buyers was conducted to collect information on market characteristics, buyers' profiles, characteristics of transacted animals, and prices of transacted animals. There are 15 cattle markets throughout the Regions of Sikasso and Koulikoro and one in the District of Bamako that encompass the Malian humid and sub-humid zones. Markets in these localities can be classified as primary (i.e., collection) markets, intermediary markets, and terminal markets. Randomly selected markets were obtained from each pool of markets. Overall, the survey took place in five terminal mar-

kets, two primary markets and one intermediary market. The market of Ouolossebougou (intermediary market) was selected but was later dropped because of calendar difficulties. The markets of Niena and Koutiala could also be classified as intermediary markets, as they supply the markets of Sikasso, Niamana, and Kati. Following the selection of markets, data were collected on transacted animals and buyers. The sample size amounts to 206. A detailed description of the variables is provided in Table 1. Data transformations such as collapsing some categories because of smaller sample size and generating dummy variables from the categorical variables were conducted. The data collected from this structured survey will be used in the analysis that will follow.

3. Descriptive analysis

A descriptive analysis was conducted using frequency distribution and central tendency on the data presented in Table 1. The purpose of the preliminary analysis is to generate a typology of cattle markets in the Malian humid and sub-humid zones to have some basic understanding of the different actors involved, the types of products sold, and the motivations of market agents.

Out of 206 observed transactions, 49% were in the Region of Koulikoro and 51% in the Region of Sikasso. Overall, 15% of the observed transactions occurred in primary markets, 9% in secondary markets, and 76% in terminal markets. The terminal markets concentrate the bulk of transactions, which can be attributed to their geographical reach as points of exports and their proximity to major urban (consumption) centers. Market agents that are considered are live cattle buyers who can be occasional buyers, breeders, traders, and meat sellers. Occasional buyers buy for familial ceremonies; breeders to build and/or improve their breeding stock; traders for resale in the same market or elsewhere; and meat sellers, who can be wholesalers or retailers, buy live animals for slaughter. Twenty-four percent of transactions were operated by butchers procuring cattle for slaughter, 60% by cattle traders procuring for resale, 6% by farmers, 2% by livestock producers, and about 3% by other buyers, including households for familial ceremonies.

Market agents' profiles are diverse. The indicators used in profiles are education, professional experience, solvency, and commercial capacity. Thirty-seven percent of buyers are illiterate, 3% can read and write in French, 10% have finished primary school, 10% have reached secondary school and beyond. About 41% attended Arabic schools. With respect to professional experience, 4% were relatively new in the business they are carrying out, 9% have accumulated between 1 and 5 years in their profession, 16% between 5 and 10 years, 68% have spent more than 10 years in their profession. The majority of these market agents (86%) operate with personal funds, 9% on credit, and about 4% mix the two. Commercial capacity measured as the number of cattle bought per week indicates that 79% of market agents procure at least 10 cattle per week, 13% procure between 1 and 3 heads per week, and about 8% between 3 and 10 heads.

Breed and category preferences are diverse and often do not match breed and category choices. The primary reason might be affordability and availability given the seasonal nature of livestock market. Five percent of buyers prefer Ndama, 27% prefer Crossbred, and 40% prefer Zebu. A sizable percentage (20%) does not differentiate between breeds. For procured cattle, 9% were Ndama, 56% were Crossbred, and 35% were Zebu. Regarding Category, 6% of surveyed market agents indicated their preference for castrated males, 15% for cows, 33% for bulls, 21% indicate a preference for adult cattle, 7% for males only, and 13% indicated preference for all categories. The categories of purchased cattle indicated that 37% were castrated males, 34% were cows, and 27% were bulls. The proportions of immature males and females in the settled transactions were minimal.

Cattle found in markets throughout the Malian humid and sub-humid zones come from a wide geographical distribution. When aggregated by agro-ecological zones within Mali, transacted cattle were reported to originate from humid and sub-humid zones with 43%, followed by North Soudanian zone with 18%, South Sahelian zone with 19%, and North Sahelian zone with 16%. A small percentage (3%) is from Burkina Faso. Fifty-four percent of purchased cattle had an average body condition, 35% had a good/excellent body condition, and 11% had a poor body condition. Similar to agro-ecological zones, purchased cattle had a variety of coat colors, which were aggregated into four distinct colors. Hence, 22% of transacted animals had white coat, 25% gray coat, 35% black coat, and 18% red coat.

Table 3 (Appendix) displays the age and price (At the time of the survey, US$ 1 was equivalent to CFA 450) of castrated males and bulls in an excellent body condition. Notwithstanding the small sample for some of the categories, average price of castrated Crossbred is higher than that of bulls of any breeds and that of castrated Zebu and Ndama as well. Average price of Ndama bull, though lower than that of the other two breeds, gives some indications that under certain circumstances, Ndama can compete against Zebu and Crossbred of comparable age categories in the humid and sub-humid zones,

especially when their relatively lower cost of maintenance, as widely documented because of their tolerance to a wide range of diseases prevalent in humid and sub-humid zones, is accounted. This would be further elucidated using the hedonic results and the derivation of the premiums and discounts attached to each attributes.

4. Estimation results of the hedonic model

Table 4 (Appendix) summarizes the results of the hedonic regression over the entire sample. For market type, the results indicate no significant difference in terms of price level between primary and terminal markets while for intermediary markets, prices are on average 13% higher compared to terminal markets. This is counter-intuitive and is probably due to sampling effects: terminal markets serve a variety of customer and include smaller animals which drive the average prices down. Intermediate markets probably serve a narrower range of buyers and categories and culled cows are more uniform. Midlevel market agents pay significantly higher price than experienced market agents. Price paid by market agents with an Arabic education is higher than that paid by illiterate market agents or those educated in the formal school system. There is no significant difference with respect to prices of settled transactions between market agents with low commercial capacity and those with high commercial capacity. The effects of age on cattle price were also ascertained. The positive sign on Age and the negative sign on Age squared indicate that cattle price increases with age up to a level before beginning to decrease, though not significantly, as age increases.

The estimation over the entire sample further indicates that Breed, Category, and Body Condition are significant determinants of cattle price and less so for Agro-ecological Origin and Coat Color. More specifically, the results indicate the marginal implicit price for Ndama is 12.4% lower than that for Zebu while the marginal implicit price for Crossbred is 9.8% lower than for Zebu. For Category, the marginal implicit of cow is 11% lower than that of bull while castrated males' marginal implicit price is 13.8% higher than that for bull. Marginal implicit price for average body condition is 18% higher than that for poor body condition. Marginal implicit price for excellent body condition is 48% higher than that for poor body condition. There is no significant difference in marginal implicit price for humid and sub-humid zones, North Sahel, South Sahel, and North Soudanian zones while marginal implicit price for gray coat is 7.8% higher than that for white coat while no significant difference was noted between the remaining colors.

The estimation was also conducted across three subsamples (cattle traders, butchers, and other buyers) to highlight the heterogeneity between market agents and the specificity of the defined professional/buyers categories in terms of how they value various attributes. The results presented in Table 5 (Appendix) indicate patterns similar to the results obtained from the entire sample with respect to the control variables with different magnitudes. The settled prices involving midlevel traders are significantly higher than those involving experienced and junior traders. Cattle traders' marginal implicit price for Ndama and Crossbred are 15% and 11% below that for zebu. Castrated males are valued 15% higher than bulls and cows are valued 26% lower than bulls. Moreover, while there is no significant difference between marginal implicit price for average body condition and that for poor body condition, marginal implicit price for excellent body condition is almost 42% higher than that for poor body condition. There was no significant difference between agro-ecological origins. Similarly, there was no significant difference between coat colors.

The estimated hedonic price for butchers (Table 6 in Appendix) indicated that none of the control variables had any significant effect on settled price. For butchers, the single most important attribute is Body Condition. Marginal implicit prices for excellent and average body condition are respectively 69% and 35% higher than that for poor body condition. Furthermore, they tend not to make any difference between coat colors, except for black, for which marginal implicit price is 16% below white coat.

The last hedonic model pertains to other agents (Table 7 in Appendix). This is a heterogeneous group, comprised primarily of buyers who are procuring cattle for familial ceremonies and, to a lesser extent, famers and livestock producers. They tend to procure younger cattle compared to butchers and traders, as illustrated by the signs and magnitudes of the parameter estimates of Age and Age squared. For this group marginal implicit price for Ndama is significantly lower relative to Zebu, marginal implicit price for castrated male significantly higher than that of bull, and marginal implicit price of excellent body condition 44% higher than that of poor body condition. An interesting finding, perhaps for superstitious reasons, is this group significantly pays less for black coat and significantly more for red coat.

5. Results of the stochastic simulation

A stochastic simulation was conducted to generate distribution on key output variables, namely, base prices, premiums, and discounts on cattle attributes. Following the approach defined in the procedural section, the stochastic averages (Table 8 in Appen-

dix) using estimates over the entire sample indicate an estimated average base price amounting to CFA 170,939 [96,976 and 279,982]. This is the amount buyer would pay for the cattle of reference (a white Zebu bull of poor body condition reported to have originated from the humid/sub-humid zone). The results also indicated that the Ndama and Crossbred were discounted relative to the Zebu with an average discount amounting to -CFA 25,398 [-134,440 and 48,566] and -CFA 21,468 [-130,511 and 52,495], respectively. Figure 1, Panel A in Appendix illustrates the distribution of base price at sample level. With respect to Ndama (Figure 1, Panel B), the distribution of the simulated premiums and discounts shows that while the breed is discounted on average, there is, respectively, 30% chance that Ndama and Crossbred would earn a premium. Similarly for Crossbred (Figure 1, Panel C) there is a 34% chance that they would earn a premium relative to Zebu.

For Category, castrated male is more valued than bull or cow. The average premium of castrated male relative to bull amounts to almost CFA 18,162 [-90,881 and 92,125]. Excellent and average body conditions are rewarded relative to poor body condition, respectively commanding a premium of almost CFA 95,501 [-13,541 and 169,465] and CFA 26,565 [82,478 and 100,529]. Figure 1, Panel D illustrates the distribution of premiums paid for Excellent Body Condition. Finally, for coat color, black coat is discounted at an average rate of -CFA 16,240 [-96,264 and 43,844] relative to white coat.

The fact that Ndama and Crossbred could earn a premium relative to Zebu is not surprising, especially to specialists of cattle marketing in Mali. The rainy season starts in March in the Malian humid zone where the Ndama and Crossbred cattle are reared, and their body condition significantly improves in early June, following two months' grazing on green pastures while the Sahel remains in the dry season until through July. Consequently, the Ndama and Crossbred in the markets are on average in a better condition than the Zebu between July and September, the time when we conducted the survey.

The average base price using the estimated parameters from the hedonic model on butchers amounts to CFA 71,361 [48,938 and 100,604]. This is the amount a butcher would pay for the cattle of reference. The results also indicated that butchers do not show any specific preference with respect to Breed, Category, and Coat color, though black coat is slightly discounted at CFA 11,641, as no significant difference was found between their marginal implicit price and that of their corresponding reference level. However, for Body Condition, butchers pay CFA 68,930 [39,687 and 100,604] premium for excellent body condition and CFA 28,050 [-1,192 and 50,473] premium for average body condition. Figure 1 illustrates the distribution of premium butchers pay for excellent body condition.

With respect to traders, base price is relatively higher than that obtained with butchers with a stochastic average estimated at CFA 185,491 [97,325 and 460, 321]. Traders value cattle type differently. They reward castrated male over bull, paying the premium of CFA 17,740 (and discount cow by CFA 48,351). Body Condition is also an important attribute. Excellent body condition earns a premium of CFA 84,102. Traders also pay attention to the agro-ecological origin of the transacted animal discounting North Sahelian cattle while paying a premium for cattle originating from the South Sahel zone (CFA 10,371) and North Soudanian (CFA 8,393). These market agents also discount black and red coat discounting each by CFA 19,370 and CFA 13,079, respectively.

Finally, base price, premiums and discounts were derived for other buyers. The average base price amounts to CFA 141,108 [91,506 and 208,190], indicating the amount paid for the cattle of reference as described earlier. This group pays significant premiums for castrated male (CFA 37,886 [-21,196 and 87,487]), excellent body condition (CFA 80,758 [13.675 and 130,359]) while discounting Ndama (-CFA 24,126 [-91,208 and 25,475]) and Crossbred (-CFA 10,765 [-77,847 and 38,836]). The results also showed that this group discounts cattle from South Sahel and North Soudanian agro-ecological zone while rewarding, though modestly, cattle from the North Sahel zone. With respect to color, black and gray coated cattle are discounted while red coat is rewarded by these particular groups of buyers.

The relative importance of each attribute was derived over estimates from the entire sample and the individual sub-samples of butchers, market agents, and other actors (Figure 2). Based on the estimation at sample level, the results indicate that Body Condition is the most important attribute contributing up to 45% in the formation of price, followed by Breed (17%), Category (15%), and Coat Color (13%). Agro-ecological was found marginal in the formation of price.

For butchers, Body Condition is also the single most important attribute, accounting for 73% of price formation and explains why the base price is lower for butchers compared to traders and other buyers. This indicates that butchers do not attach much importance on Breed, Category, Agro-ecological origin, or Coat Color. These operators are driven by profitability after slaughter; hence, the importance of Body Condition. Traders, especially those buying in terminal markets, very seldom hold onto cattle for

long. In fact, some conclude a deal to just turn around and sell the same animal without bearing any additional charges, thus making a quick profit. Hence, for these market agents, the relative importance of each attribute is more uniform with Body Condition (32%), Category (22%), and Breed (20%) being the most important. Agro-ecological origin and Coat Color are the least important of the five with 14% and 12%, respectively. This is consistent with livestock trading business in West Africa in general and Mali in particular. Similar to traders, the attributes' weights based on estimates from the sub-sample of other buyers are evenly distributed although Body Condition (30%) and Agro-ecological Origin (24%) are the two most important. The fact that this is a heterogeneous group renders any explication difficult to make. This group is largely comprised of occasional buyers who, for superstitious reasons, favor one coat color over another when purchasing for familial ceremonies. This was previously explained with regard to the discounts over black coat compared to white coat and explains the relative importance of Coat Color (19%) compared to the other sub-sample of buyers. Category and Breed also are important to this group.

Conclusions

Hedonic price analysis was shown to be an effective method for identifying and ranking factors affecting the purchase prices of cattle throughout value chains in the sampled locations. A relatively limited effect of market characteristics on settlement prices was found. Market agent profiles, with the exception of Commercial Capacity, have been found to have some effect on price formation. However, heterogeneity within the types of market agent in the current study is apparent, and requires further study to fully identify and isolate these effects.

The current study's results include an anomaly in that butchers' average prices are below those of other chain stages' (albeit with a large standard deviation). This could be explained by the fact that these market agents based their decision to purchase primarily on a single attribute. It could also be due to sampling bias, in that butchers serve a wider range of clientele than do the other actors and so may exhibit a broader price range. It does not, however, affect the validity of results, which relate prices to other variables within observations only.

Price has also been found to be sensitive to cattle age, with a non-linear relationship. Controlling for these factors, the hedonic estimation has shed some light on the relationship between cattle attributes and prices. Breed, Category, Body Condition, Agro-ecological Origin, and Coat Color, to varying degrees, are determinants of cattle price. The various attributes were classified by order of importance in terms of their impact on prices. Body Condition, Breed, and Category are the three most important attributes regardless of the stage of the value chain being examined. Agro-ecological Origin and Coat Color are less significant, except in the case of other buyers and, to a lesser extent, when the analysis is done at sample level. The importance of Body Condition illustrated by the high premium rates paid for excellent body condition across all levels of analysis, combined with the relatively low discount rates on Ndama and Crossbred further confirms that if all maintenance costs are accounted for, Ndama cattle with excellent body condition could be as profitable as Zebu. This could be further ascertained by exploiting the seasonal feed patterns to benefit Ndama producers through higher prices. This may best be addressed by collective action in marketing by timing the decision to destock to coincide with the periods of low feed availability in the Sahel. This may well suit the community-based resource management that allows best use of the Ndama in that regard.

The findings have production and marketing implications, as they would enable Ndama producers and traders to make more informed production and marketing decisions, as they are better informed about how the attributes of cattle they put on the market are rewarded or penalized. From a marketing standpoint, information on buyers' valuation of cattle attributes would be helpful in the price discovery process, especially in the West Africa sub-region where prices are set through eyeballing. These implicit prices of cattle attributes could also be the basis for an effective market information system that could reduce unfair practices from market intermediaries and traders who, because of their superior knowledge about markets' conditions, which they use to their benefits, are usually blamed for low producer prices. If appropriately used, these findings could enhance the efficiency of the cattle pricing system and consequently improve the livelihoods of poor cattle keepers in the Malian humid and sub-humid zones.

The findings also have important AnGR management implications. The fact that buyers, in general, reward excellent body condition more than they penalize less desirable breeds make the case against the needs for farmers to crossbreed for pecuniary reasons. The analysis clearly indicates there are significant incentives for excellent body condition that exceed the disincentives of less desirable breeds. The derived marginal implicit price would help producers involved in animal fattening and breeding to know which attribute or combination of attributes to target to achieve financial success for their operations.

Although crossbreeding may lead to higher prices, selection within the breed and fattening are the best avenues that could lead to better prospects for Nda-

ma producers, as they also lead to better price while protecting the breed for future use. Under such a strategy, Ndama would continue to play a central role in livestock productions systems in the humid and subhumid zones of Mali and its socio-economic, cultural, historical, and ecological values not captured by the markets would not be lost. This would require some investments by Ndama producers, which could help sustain any gains in quality as long as the market continues to reward attributes such as excellent body condition more so than they penalize a particular breed. Under this paradigm, Mali would be better positioned to face the constraints related to the preservation of Ndama and the environment to which they are well adapted. This could contribute to laying the foundation of livestock production system throughout West and Central Africa. Such an endeavor would be particularly important for Sierra Leone and Liberia, two post-war countries where trypanosomosis is endemic and whose livestock was decimated by prolonged warfare and in Central Africa which has been done in the past, which would continue to expand the geographic dispersion of Ndama.

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Appendix

Table 1. Description of the information collected in the structured survey

Variables	Variable definition
Region	To indicate the region where survey took place (Koulikoro and Sikasso)
Circle	To indicate the circle where the markets are located (Diola, Kati, Bamako, Bougouni, Koutiala, and Sikasso)
Market	To indicate the market where the interviews were held (Ngolobougou, Ouelessebougou, Niamana, Kati Draal, Koumantou, Dogonasso, Sikasso, Niena, Koutiala)
Market type	Categorical variable to indicate the type of market where transaction occurred (primary market, intermediary market, and terminal market)
Profession	Categorical variable to indicate buyer's profession (butcher, cattle trader, and other market agent)
Experience	Categorical variable to indicate buyer's professional experience (less than 1 year, between 1 and 5 years, between 5 and 10 years, and more than 10 years)
Education	Categorical variable to indicate buyer's level of education (illiterate, read and write, primary school, secondary school, beyond secondary, and Arabic education)
Commercial capacity	Categorical variable in number heads of cattle sold per week to indicate the size of buyer's business (between 1 and 3 heads, between 3 and 5 heads, between 5 and 7 heads, more than 7 heads)
Mode of payment	Categorical variable to indicate how transaction is settled (own funds, credit, combination of credit and own funds, and other)
Preferred breed	Categorical variable to indicate the buyer's breed preference (Ndama, Crossbred, Zebu)
Purchased breed	Categorical variable to indicate the breed of the purchased cattle (Ndama, Crossbred, Zebu)
Preferred category	Categorical variable to indicate the buyer's category preference (castrated males, cows, immature males, immature females, and bulls)
Purchased category	Categorical variable to indicate the buyer's category of purchased cattle (castrated males, cows, immature males, immature females, and bulls)
Reason for purchase	Categorical variable to indicate the reason for purchasing this particular cattle (carcass yield, price affordability, reproductive potential, resistance to diseases, ruggedness, and other)
Body condition	Categorical variable to indicate the body condition of the purchased cattle (poor, average, good/excellent)
Age	Continuous variable to indicate the age of the purchased cattle
Price	Continuous variable to indicate the price of the purchased cattle

Table 2. Description of the explanatory variables used in the model

Variable	Level	Description
Market type	Primary	Dummy variable (1 if market is primary and 0 otherwise)
	Secondary	Dummy variable (1 if market is intermediary and 0 otherwise)
Professional experience	Junior	Dummy variable (1 if buyer is a junior level market agent and 0 otherwise)
	Mid level	Dummy variable (1 if buyer is amid-level market agent and 0 otherwise)
Education level	Educated	Dummy variable (1 if market agent has a formal education and 0 otherwise)
	Arabic	Dummy variable (1 if market agent has Arabic education and 0 otherwise)
Trading capacity	High	Dummy variable (1 if market agent has a high trading capacity and 0 otherwise)
Purchased breed	Ndama	Dummy variable (1 if purchased cattle is of the Ndama breed and 0 otherwise)
	Crossbred	Dummy variable (1 if purchased cattle is a Crossbred and 0 otherwise)
Cattle category	Castrated	Dummy variable (1 if purchased cattle is a castrated male and 0 otherwise)
	Cows	Dummy variable (1 if purchased cattle is a cow and 0 otherwise)
Body condition	Average	Dummy variable (1 if purchased cattle has an average body condition and 0 otherwise)
	Excellent	Dummy variable (1 if purchased cattle has an excellent body condition and 0 otherwise)
Agro-ecological origin	North Sahel	Dummy variable (1 if purchased cattle is from localities within the region of Mopti, including the Delta and 0 otherwise)
	South Sahel	Dummy variable (1 if purchased cattle is from localities within the region of Segou and Kayes and 0 otherwise)
	North Soudanian	Dummy variable (1 if purchased cattle is from the district of Bamako and localities within the region of Koulikoro and 0 otherwise)
Coat color	Red	Dummy variable (1 if purchased cattle has a red coat and 0 otherwise)
	Gray	Dummy variable (1 if purchased cattle has a gray coat and 0 otherwise)
	Black	Dummy variable (1 if purchased cattle has a black coat and 0 otherwise)

Table 3. Average age (year) and price (CFA) of transacted breeds in good to excellent body condition

	Castrated			Bull		
	N	Age	Price	*N*	Age	Price
Ndama	8	7	200,625	2	8	180,000
Crossbred	20	6	237,300	2	6	198,500
Zebus	8	7	206,250	29	6	233,448

Notes: US$ 1 was equivalent to CFA 450 at the time of the survey.

Table 4. Results of hedonic model over the entire sample

Variable	Level	Parameter estimates	Robust standard errors	*P*-values
	Constant	11.091	0.203	0.000
Cattle age	Age	0.520	0.223	0.021
	Age squared	-0.089	0.083	0.283
Market type	Primary	-0.018	0.050	0.719
	Secondary	0.134	0.065	0.041
Professional experience	Junior	-0.039	0.051	0.453
	Mid level	0.135	0.048	0.006
Education level	Educated	-0.022	0.040	0.579
	Arabic	0.100	0.041	0.017
Trading capacity	High	-0.005	0.040	0.906
Purchased breed	Ndama	-0.124	0.056	0.027
	Crossbred	-0.098	0.046	0.034
Cattle category	Castrated	0.138	0.063	0.031
	Cows	-0.111	0.043	0.011
Body condition	Average	0.181	0.070	0.011
	Excellent	0.480	0.062	0.000
Agro-ecological origin	North Sahel	-0.027	0.072	0.710
	South Sahel	-0.032	0.085	0.708
	North Soudanian	0.048	0.058	0.409
Coat color	Red	-0.035	0.075	0.640
	Gray	0.078	0.041	0.058
	Black	-0.063	0.041	0.126
Sample size		206		
Goodness of fit		0.57		

Table 5. Hedonic estimation over the sub-sample of cattle traders

Variable	Level	Parameter estimates	Robust standard errors	*P*-values
	Constant	11.178	0.263	0.000
Cattle age	Age	0.612	0.279	0.031
	Age squared	-0.119	0.107	0.266
Market type	Primary	-0.013	0.069	0.852
	Secondary	0.136	0.069	0.050
Professional experience	Junior	-0.063	0.083	0.450
	Mid level	0.218	0.070	0.002
Education level	Educated	-0.085	0.078	0.274
	Arabic	0.057	0.075	0.442
Trading capacity	High	-0.052	0.062	0.404
Purchased breed	Ndama	-0.149	0.076	0.052
	Crossbred	-0.113	0.063	0.076
Cattle category	Castrated	0.137	0.079	0.085
	Cows	-0.256	0.088	0.004
Body condition	Average	0.107	0.103	0.304
	Excellent	0.420	0.094	0.000
Agro-ecological origin	North Sahel	-0.082	0.106	0.442
	South Sahel	0.101	0.129	0.437
	North Soudanian	0.090	0.070	0.199
Coat color	Red	-0.063	0.098	0.518
	Gray	0.051	0.061	0.401
	Black	-0.046	0.061	0.447
Sample size		124		
Goodness of fit		0.57		

Table 6. Hedonic estimation over the sub-sample of butchers

Variable	Level	Parameter estimates	Robust standard errors	*P*-values
	Constant	11.103	0.979	0.000
Cattle age	Age	-0.053	0.950	0.956
	Age squared	0.127	0.243	0.607

Table 6 (cont.). Hedonic estimation over the sub-sample of butchers

Variable	Level	Parameter estimates	Robust standard errors	*P*-values
Market type	Primary	ne	ne	ne
	Secondary	ne	ne	ne
Professional experience	Junior	-0.209	0.055	0.001
	Mid level	-0.090	0.084	0.291
Education level	Educated	0.016	0.045	0.722
	Arabic	0.040	0.074	0.591
Trading capacity	High	-0.004	0.161	0.978
Purchased breed	Ndama	-0.009	0.066	0.887
	Crossbred	0.113	0.076	0.150
Cattle category	Castrated	0.073	0.106	0.498
	Cows	0.052	0.095	0.592
Body condition	Average	0.348	0.138	0.017
	Excellent	0.693	0.160	0.000
Agro-ecological origin	North Sahel	0.066	0.062	0.294
	South Sahel	0.025	0.085	0.769
	North Soudanian	-0.004	0.112	0.970
Coat color	Red	-0.011	0.069	0.872
	Gray	-0.008	0.086	0.931
	Black	-0.161	0.053	0.005
Sample size		50		
Goodness of fit		0.68		

Note: ne indicates that the corresponding variable was not specified in the model.

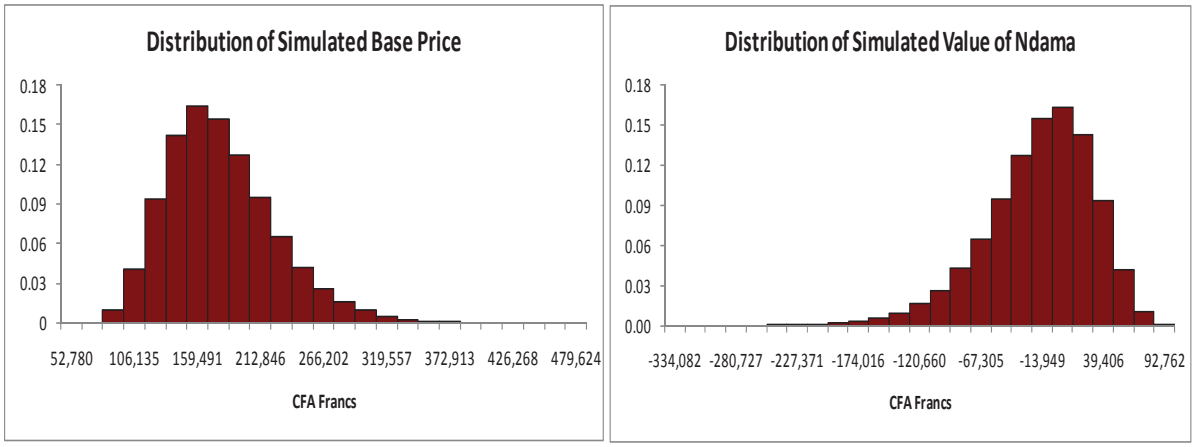
Table 7. Hedonic estimation over the sub-sample of other buyers

Variable	Level	Parameter estimates	Robust standard errors	*P*-values
	Constant	11.835	0.159	0.000
Purchased breed	Ndama	-0.166	0.145	0.267
	Crossbred	-0.057	0.113	0.617
Cattle category	Castrated	0.260	0.105	0.023
	Cows	-0.017	0.088	0.849
Body condition	Average	0.005	0.096	0.956
	Excellent	0.475	0.144	0.004
Agro-ecological origin	North Sahel	0.092	0.156	0.563
	South Sahel	-0.325	0.106	0.007
	North Soudanian	-0.087	0.073	0.249
Coat color	Red	0.214	0.077	0.012
	Gray	-0.057	0.083	0.505
	Black	-0.060	0.088	0.502
Sample size		32		
Goodness of fit		0.67		

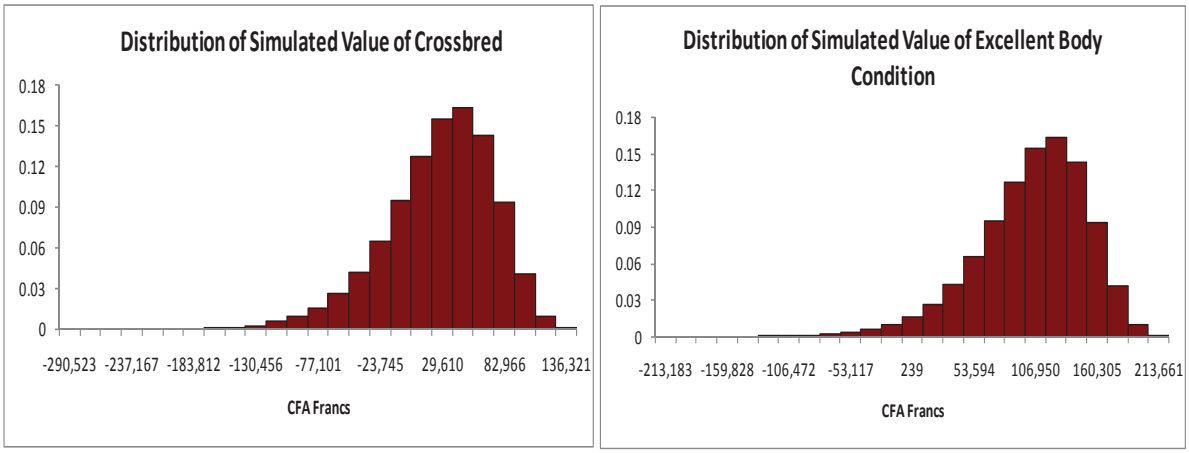
Table 8. Stochastic average of base prices, premiums, and discounts across level of analysis in CFA

		Level of analysis			
Variable	Level	Sample	Butchers	Traders	Other buyers
Price	Base price	170,939	71,361	185,491	141,108
Purchase breed	Ndama	-25,398	-1,857	-32,949	-24,126
	Crossbred	-21,468	7,164	-27,265	-10,765
Cattle category	Castrated	18,162	4,105	17,740	37,886
	Cows	-23,445	2,521	-48,351	-5,394
Body condition	Average	26,565	28,050	11,619	-2,332
	Excellent	95,501	68,930	84,102	80,758
Agro-ecological origin	North Sahel	-10,512	3,577	-22,290	10,229
	South Sahel	-11,290	601	10,371	-41,333
	North Soudanian	1,991	-1,493	8,393	-14,579
Coat color	Red	-11,843	-1,978	-19,221	29,829
	Gray	7,235	-1,723	966	-10,664
	Black	-16,240	-11,641	-16,370	-11,172

Notes: 1 US$ was equivalent to CFA 450.



Panel A Panel B



Panel C Panel D

Fig. 1. Distribution of simulated base price and attributes' values at sample level

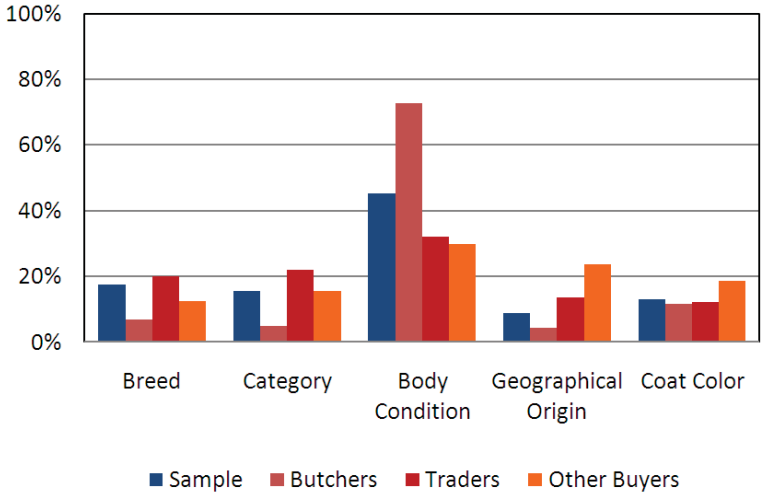


Fig. 2. Relative importance of cattle across various levels of analysis