Dairy Market Participation with Endogenous Livestock Ownership: Evidence from Cote d'Ivoire

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Abstract
This study evaluates determinants of dairy market participation by agricultural households in Cote d'Ivoire by using the Heckman selection model to correct for endogenous cattle ownership. A key result is that ignoring the population of non-owners biases estimates of market participation parameters. These findings are important in light of the widespread application of livestock market participation analyses that assume cattle ownership is exogeneous.

Keywords: Cote d'Ivoire, dairy, endogenous adoption, Heckman selection model, market participation

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Increasing participation in agricultural markets is a key factor to lifting rural households out of poverty in Africa countries (e.g., Delgado 1995). Markets represent a channel for sectoral and macro economic policies that aim to improve welfare of peasants households. Stimulating participation of subsistence farmers into market will help them to benefit from these economic opportunities and is relevant to achieve food security and poverty alleviation. Yet the economic literature on market participation, while growing in scope and depth, continues to be relatively thin (Bellemare and Barret 2006).

The typical approach in the extant literature is to divide the market-participation decision into two stages. In the first stage, households that produce a particular commodity decide whether to be net buyers, net sellers, or autarkic in the market for that commodity. In the second stage, net buyers and net sellers determine the extent of market participation. This two-stage conceptual model of market participation lends itself to econometric models that address sample selection, such as Heckman's two-stage approach (Heckman 1979). For applications to agricultural market participation in developing-country settings, see for example Goetz (1992); Holloway et al. (2000); Holloway, Barrett, and Ehui (2005); and Bellemare and Barret (2006). While this literature has evolved to refine the econometric models, the basic conceptual approach remains.

However, the extant literature ignores an important stage of the household marketing decision, as well as a second source of potential sample selection; namely, the decision to produce a commodity in the first place. The papers listed above observe only those households that produce the (potentially) marketed commodity. For example, studies that address

participation in dairy markets sample only households that own livestock (e.g., Holloway, Barret, Ehui 2005; Bellemare and Barret 2006). However, livestock ownership is the result of an economic decision made by households; that is, livestock owners are self-selected. As a result, existing estimates of the determinants of market participation may be biased. Moreover, even if this potential source of sample selection is not an issue—which is an empirical question—inference from the existing research is necessarily limited to producing households, and thus are not of use for informing the design and evaluation of, for example, development projects aimed at increasing market participation by encouraging livestock ownership.

This paper seeks to address this void in the market participation literature. To our knowledge, it is the first market participation study that specifically treats endogenous ownership of productive capital (livestock). In addition to correcting for a potentially important source of bias, our approach also allows us to extend inference to a broader population of rural households. For example, we are able to evaluate the implications of higher market prices or lower transactions costs for not only the volume of marketed surplus from existing cattle owners, but also for the propensity of rural households more broadly to adopt livestock. Our analysis of rural dairy markets in Cote d'Ivoire also represents a rare look at market participation in West Africa.

The rest of the paper is structured as follows. In the next section, we give an overview of the relevant literature on market participation by rural households in developing countries. We then lay out a theoretical model of household participation in dairy markets that explicitly captures the discrete livestock ownership decision, and briefly present the Heckman sample selection model that treats sales as a censored dependent variable. After briefly describing the

data, we present and discuss econometric results. The last section closes this paper with concluding remarks and policy implications.

Previous Work on Agricultural Market Participation among Agrarian Households

Participation in agricultural markets by rural households is an important strategy for poverty alleviation and food security in developing countries (Heltberg and Tarp 2001). Peasant farmers communities are among the poorest and the largest in developing countries, so policies that stimulate their interaction in the exchange economy will enhance economic growth.

However, agricultural households often face imperfect or incomplete markets for some goods and factors, which are then non-tradable and production and consumption decisions are no longer separable (Sadoulet and de Janvry 1995). Sadoulet and de Janvry (1995) summarize the sources of incomplete or imperfect markets facing agrarian households, including costs resulting from distance from markets, poor infrastructure, high marketing margins, imperfect information, supervision and incentive costs. Hence the literature's interest in the effects of transactions costs on market participation (e.g., Ehui, Benin, Paulos 2003; Goetz 1992; Holloway, Barrett, and Ehui 2005; Holloway and Ehui 2002; Holloway et al. 2004; Key, Sadoulet, and de Janvry 2000; Staal, Delgado, and Nicholson 1997; Zaibet and Dunn 1998). As a result, the reduction of transactions costs, as a means of increasing market participation, has been identified as a goal of development policy (e.g., Delgado 1995).

In the case of dairy markets, perishability and bulkiness of raw milk add additional transactions costs (Holloway et al. 2000). The perishability of milk increases the likelihood of product spoilage and losses during milk processing or transport. The associated costs reduce the profitability of marketing milk. Holloway et al. (2000) used a tobit analysis of marketable

milk surplus to explore the impact of household-level transaction costs and the choice of production technique on the decision of peri-urban Ethiopian farmers to sell fluid milk to marketing cooperatives. The variables considered were capital stock (cross bred and indigenous bred), intellectual capital (experience, education and extension), provision of infrastructure (time to transport milk to market). Holloway et al. (2004) performed a Bayesian procedure to mitigate bias coming from assuming that the true point of censoring in the tobit regression is zero. They investigated the consequences of this incorrect assumption by using data on milk market participation in the Ethiopian highlands. Bellemare and Barrett (2006) estimated a two stage model of livestock market participation by herders in Eastern Africa. Their results indicated that prices matter to the amount of participation and fixed cost matter to both participation and amount of participation.

The empirical applications in the extant literature focus only on pastoralists or livestock owners, seeking to explain why some livestock owners participate in the market economy while others do not. However, as discussed in the introduction, livestock ownership is the result of an economic decision, and thus ignoring non-owners may result in sample selection bias. Conceptually, low milk prices or high transactions costs may discourage some households from owning livestock. In the next section we extend the standard conceptual framework for market participation to model livestock ownership explicitly.

Theoretical Framework for Analyzing Dairy Market Participation

We follow much of the recent market-participation literature in modeling dairy market participation as a two-step procedure, a market participation decision followed by a sales volume decision. Market participation, in this case, is defined as livestock ownership.

Application of Heckman's (1979) two step procedure consists of using a probit in the first stage (livestock ownership) as follows:

(1) $\Pr(Z_i = 1 | w_i, \alpha) = \Phi(h(w_i, \alpha)) + \varepsilon_i$

where Z_i is an indicator variable equal to unity for households that own livestock, Φ is the standard normal cumulative distribution function, the w is a vector of factors affecting market participation, the α is a vector of coefficients to be estimated, and ε_i is the error term assumed to be distributed normally with a mean of zero and a variance σ^2. The variable Z_i takes the value of 1 if the marginal utility the household i gets from participating in market is greater than zero, and zero otherwise. So we have:

(2) $Z_i^* = \alpha w_i + \nu_i$

where Z_i^* is the latent level of utility the household gets from livestock ownership (i.e., market participation, $\nu_i \sim N(0,1)$ and,

(3) $Z_i = 1$ if $Z_i^* > 0$,

(4) $Z_i = 0$ if $Z_i^* \leq 0$

In the second step, the inverse of mills ratio (IMR) is added as a regressor in the sales function regarding level of participation in order to correct for potential selection bias. If only the households who participate in the market are included in the second step, the IMR is computed as following

(5) $\hat{\lambda} = \dfrac{\phi(h(w_i, \hat{\alpha}))}{\Phi(w_i, \hat{\alpha})}.$

where $\phi(.)$ is the normal probability density function. The second-stage (sales) equation is then given by:

(6) $E(Y_i | Z = 1) = f(x_i, \beta) + \gamma \dfrac{\phi(h(w_{i,} \hat{\alpha}))}{\Phi(w_i, \hat{\alpha})}$

where *E* is the expectation operator, *Y* is the (continuous) extent of market participation, or sales, *x* is a vector of independent variables affecting sales, and β is the vector of the corresponding coefficients to be estimated.

So Y_i can be expressed as following:

(7) $$Y_i^* = \beta' x_i + \gamma \hat{\lambda}_i + u_i$$

where $u_i \sim N(0, \sigma_u)$. Y_i^* is only observed for cattle owners ($Z_i = 1$), in which case $Y_i = Y_i^*$.

The livestock ownership regression (2) and the milk sales regression (7) are jointly estimated by full maximum likelihood using the *Heckman* procedure in STATA.

Data and Descriptive Statistics

Data were collected from 185 agricultural households in the *Savane* province in northern Cote d'Ivoire where 85 percent of that country's livestock exist—essentially all of these owned by small holders—and where there is potential for milk production and marketing. Cropping activities such as cotton, cashew nuts, mangoes, maize dominate the agricultural production in this province. Most livestock owners earn most of their income from crop agriculture, and, although draft power is used in most cotton plantations, cattle are not integrated into the agricultural production system (Barry 2001). Livestock are mainly kept as a form of wealth.

The sampling method used for data collection was designed in two steps. First, the district of Khorogo was selected as the milk shed because of the relatively large share (42%) of milk production in the province (Atse 1990). In the second stage, 50 villages were selected along 6 main transportation routes linking producers in rural areas and consumers in the district capital. Criteria of selection were distance to district town market and milk production. In each village, an average of 3 or 4 households were selected randomly from the population of livestock owners and non livestock owners. The resulting sample includes 99 sedentary

agricultural households with livestock and 86 agricultural households without livestock were interviewed.

The survey was administered in November 2006. Data were collected on household characteristics, household assets, transaction costs, access to information, extension, and credit services, and commodity prices. The unit of observation is the household, which in the case of livestock owners is extended to include the family of the livestock keeper. The household head is the decision maker regarding cow adoption. However, livestock owners typically lack livestock management skills, so daily cow management is typically performed by a hired Fulani or Peulh laborer with appropriate skills. Milk production is sold by the hired livestock keeper who gets the entire revenue as a complement to his cash salary. In some cases, the livestock owner may instruct the livestock keeper to leave the whole milk production to the calves to get healthier animals. Negotiated monthly cash salary for livestock keepers varies between 5,000 and 20,000 F.CFA, depending on herd size, and the extent to which the livestock owner requires the keeper to leave milk for the calves.

Descriptive statistics for key variables are presented in table 2. Some differences between livestock owners and non-owners emerge from the summary statistics. Livestock owners are generally older and also wealthier than non-owners as indicated by ownership of assets. Livestock, while used for draught power and for milk, are also, and perhaps mainly, a form of wealth which may take time to accumulate. So, it is not surprising that livestock owners are, on average, older than non-owners.

Livestock owners on average are located farther from the district market, perhaps because of greater availability of land for grazing. Livestock owners have on average twice the education as non-owners, although neither group has more than one year of schooling. Most of

the households surveyed who belong to the Peulh tribe are livestock producers. Indeed, the Peulh have a tradition of livestock management, and cattle rearing represent their primary activity.

Marketed milk is sold mainly in fresh (raw) form. A small portion (approximately 10 percent) of sales is in the form of sour milk or butter. This study focuses on fresh milk sales. The simple average selling price of fresh milk is 131 F.CFA per liter, while the average purchase price for non-owners is 123 F.CFA per liter.

The average herd for livestock owners consists of 9 local dairy cows and 11 African cross-bred dairy cows. No exotic crossed breeds appear in the herds surveyed. The principal reason given by the households is the high cost of managing these cows. They require intensive care and are very sensitive to local diseases. Livestock owners receive an average of three extension visits annually. Livestock keepers earn an average monthly salary of 13,000 F.CFA per month.

Empirical specification

Equation (1) was used to predict the probability that a given household will adopt livestock. Then, determinants of milk sales, conditional on livestock ownership, are analyzed in the second step through equation (7). Using livestock ownership in the first stage of the marketing decision is a departure from the extant literature, which typically uses discrete net sales position (net buyer, autarkic, or net seller) as the first stage in the marketing decision. We do not estimate the net position because of 99 livestock owners, 88 are net milk sellers and 11 are autarkic. No livestock owners are net buyers of milk. So, the vast majority of households who own cows also sells milk. In this case, the market participation is highly for likely households

owning cows. In this sense, livestock ownership is the relevant discrete market participation decision.

The livestock ownership regression, equation (1), was specified with a number of variables included to capture human capital, and wealth, market prices, and transactions costs associated with marketing milk. Variables used to specify equation (1) are described in table 2a. We include the household head's age and ownership of assets as proxies for wealth, and expect these to have a positive effect on livestock ownership. We include land area exploited as a measure of income from crop agriculture, which has an *a priori* ambiguous effect on livestock ownership. The larger is the land area exploited, the greater is the household's income, and the more likely is the household to own cattle. However, greater land area exploited might also indicate a specialization in crop agriculture, in which case livestock ownership may be less likely. We also expect milk prices to be positively correlated with livestock ownership, as high milk prices increase returns to selling milk. The effect of distance to the district capital on livestock ownership is *a priori* ambiguous. Transport costs associated with selling milk increase with distance to market. However, as mentioned above, grazing land may be more available further from town. Finally, membership in the Peulh tribe is expected to increase the likelihood of livestock ownership because of this tribe's tradition of livestock management.

The milk sales regression, equation (7), was specified with a number of variables included to capture human capital, market prices, and transactions costs associated with marketing milk. Variables used to specify equation (7) are described in table 2b. Like much of the previous research, we include number of local cows and number of cross-bred cows, and expect sales to increase in number of all cows *ceteris paribus*, with a larger effect for cross-

bred cows(e.g., Bellemare and Barrett 2006; Holloway, Barrett, and Ehui 2005; Holloway et al. 2000). We also include the number of extension visits under the hypothesis that such technical assistance enhances milk productivity and increases milk sales. Milk sales are expected to increase in milk price and decrease in the livestock keeper's wage. We include family size, but do not have a basis for signing the effect *a priori*; larger families likely consume more milk, thus decreasing milk sales, but also have additional labor, which may increase milk sales. Distance to the district town of Khorogo is included as a measure of transport costs associated with selling milk. Also, we allow the intercept to differ across transportation routes.

Econometric identification is made possible by the inclusion of wealth measures (number of televisions, number of refrigerators), human capital of the household head, and the indicator variable for membership in the Peuhl tribe, in the livestock ownership regression, and not in the milk sales regression. We think that proxies for wealth do not influence the volume of milk sold by the livestock keeper. Indeed, these wealth measures are specific to the household head and, because of the labor division described above, they are not expected to influence the livestock enterprise managed somewhat autonomously by hired labor. Similarly, education of the household head is not expected to influence the management of livestock since the livestock owner is typically not directly involved in cattle management. The ethnicity of the household head is also not expected to affect milk sales.

Results

Results of the livestock ownership regression are reported in table 3, with White's robust standard errors reported in parentheses. In addition to the model estimates, we also report the marginal effect of each factor on the likelihood of cattle ownership. We find that adoption of

cattle in Cote d'Ivoire is influenced strongly by household characteristics, geography, and the fresh milk market price. All these effects have expected signs.

The likelihood of owning livestock increases with the age of the household head, *ceteris paribus*. Ownership of a television and refrigerators also increase likelihood of livestock ownership. These results for age and household assets are consistent with the hypothesis that a certain level of wealth is required to acquire livestock. The effect of education is of the expected sign, but not statistically significant.

The likelihood of livestock ownership is also increasing in the market price of fresh milk. This result supports our hypothesis that livestock ownership is indeed responsive to market signals. Thus, the previous literature on dairy market participation, which typically observes only livestock owners, may be missing an important source of sample selection bias.

Distance to the district town of Korogho is positive and statistically significant, indicating that the benefits of being far from town, such as greater availability of pasture land, outweigh the additional transactions costs of selling milk.

As expected, membership in the Peulh tribe increases the likelihood of livestock ownerships. These results are in line with Barry (2001) who found in analyzing determinants of small ruminants' adoption in the peri-urban region of Khorogo, that age and Peulh ethnic background enhance the probability of livestock adoption.

Finally, the route dummies pick up significant regional differences in livestock ownership. Households along the Boundiali route are much more likely to own livestock, and households along the Mbengue and Sirasso routes are less likely to own livestock. These dummy variables may be picking up systematic differences in transactions costs (i.e., perhaps

the road from Boundiali to Khorogo is in better condition than others) and/or unobserved household characteristics.

Results of the net milk sales regression are reported in table 4, with White's robust standard errors in parentheses. Milk sales are increasing in all three variables associated with the household head (age, family size, and land area farmed), although only age and land area are statistically significant. These findings suggest that the division of labor discussed above is not complete; that is, livestock owners have some influence over milk marketing decisions.

Milk sales are increasing in the market price, as expected, but the effect is statistically insignificant. Milk sales are decreasing in the livestock keeper's salary, also as expected. This result is consistent with the observation that income from milk sales is a form of remuneration for the livestock keeper. Owners who pay higher salaries may also discourage milk sales, income from which is typically kept by the livestock keeper. More milk is available to calves, which encourages calf growth and thus increases the wealth of the livestock owner.

As expected, milk sales are increasing in the number of both local cows and African cross-bred cows, *ceteris paribus*, and slightly more so for the latter, which is consistent with findings from previous research (e.g., Holloway et al. 2000, Ehui, Benin, and Paulos 2003, Lapar, Holloway, and Ehui 2003). Milk sales are also increasing in the number of extension visits, perhaps because technical assistance increases production and thus sales.

We find a regional pattern in milk sales, with households along the Napie, Sucaf, and Mbengue routes marketing more milk than households in other regions, *ceteris paribus*.

We also report in table 4 the estimated correlation across equation errors, ρ, and, for the sake of comparison, direct OLS estimation of equation (7);that is, estimates of a model of milk sales that ignores sample selection. We conduct a Wald test of the hypothesis that equations (2)

and (7) are independent (i.e., $\rho = 0$), and strongly reject the hypothesis. Thus, these data support the claim that livestock ownership is self-selected. Therefore, analysis that uses these data to study milk sales, but which ignores selection in cattle ownership, suffers from sample selection bias.

Conclusion

Application of the Heckman selectivity model was used to assess factors affecting milk sales among rural households in Cote d'Ivoire. We depart from the extant literature by controlling for selection into livestock ownership. We find that cattle ownership is self-selected, so that an analysis of milk sales that ignores the cattle ownership decision would suffer from sample selection bias. To our knowledge, the entire literature on dairy market participation has ignored cattle ownership. Thus this study has potentially important implications for the agricultural market participation literature and for designing and evaluating development programs aimed at encouraging household marketing of agricultural products. In addition to correcting for a potentially important source of bias, our approach also allows us to extend inference to a broader population of rural households. For example, we are able to evaluate the implications of higher market prices or lower transactions costs for not only the volume of marketed surplus from existing cattle owners, but also for the propensity of rural households more broadly to adopt livestock. Finally, our analysis of rural dairy markets in Cote d'Ivoire also represents a rare look at livestock market participation in West Africa.

On-going work is extending this research in several dimensions. We are attempting to model explicitly a clustered error structure that allows heteroscedasticity across the 50 villages, although preliminary work indicates little change from the results reported here. We are also evaluating an extension of the model used here to explicitly capture the discrete marketing

decision conditional on livestock ownership. Such a model would be a more direct extension of the standard, two-stage model (discrete decision of direction of market participation, followed by extent of market participation conditional on direction of market participation) to allow for self-selection in livestock ownership.

References

Atse, A.P. 1990. “La Production Laitière dans le Nord de la Cote d’Ivoire: Situation Actuelle et Analyse d’Eléments pour une Organisation Rationnelle et une Meilleure Valorisation.” Rapport-Ministère de la Production Animale- Service Zootechnie 187p.

Barry, M.B. 2001. “The Determinants of Urban Livestock Adoption in the Zone dense of Khorogo (Northern Cote d’Ivoire): A Tobit Approach.” Ph D Dissertation, Oklahoma State University, Department of Agriculture and Natural Resources.

Bellemare, M.F., and C.B. Barrett. 2006. “An Ordered Tobit Model of Market Participation: Evidence from Kenya and Ethiopia.” *American Journal of Agricultural Economics* 88(20):324-337.

Delgado, C. 1995. *Africa’s Changing Agricultural Development Strategies : Past and Present Paradigms As a Guide to the Future*, IFPRI.

Ehui, S., S. Benin, and Z. Paulos. 2003. “Policy Option for Improving Market Participation and Sales of Smallholder Livestock Producers: A Case Study of Ethiopia.” Paper submitted to the 2nd EAF International Conference on Contemporary Development Issues in Ethiopia. Addis Ababa, Ethiopia.

Goetz, S. 1992. “A Selectivity Model of Household Food Marketing Behavior in Sub-Saharan Africa.” *American Journal of Agricultural Economics* 74, 444–452.

Heckman, J.J. 1979. “Sample Selection Bias as a Specification Error.” *Econometrica* 47(1):153-161.

Heltberg, R., and F. Tarp. 2001. “Agricultural Supply Response and Poverty in Mozambique.” Presented Paper at the Conference on Growth and Poverty at WIDER. 25-26 May 2001, Institute of Economics, University of Copenhagen.

Holloway, G.J., C. Nicholson, C. Delgado, S. Staal, and S. Ehui. 2004. “A revised Tobit Procedure for Mitigating Bias in the Presence of Non-Zero Censoring with an Application to Milk Market Participation in the Ethiopian Highlands.” *Agricultural Economics* 31: 97-106.

Holloway, G.J., C. Nicholson, C. Delgado, S. Ehui, and S. Staal. 2000. “Agroindustrialization through Institutional Innovation: Transaction Costs, Cooperatives and Milk Market Development in the East African Highlands.” *Agricultural Economics* 23, 279-288.

Holloway, G.J., and S. Ehui. 2002. “Expanding Market Participation Among Smallholder Livestock Producers: A Collection of Studies Employing Gibbs Sampling and Data from the Ethiopian Highlands, 1998-2001.” Socioeconomics and Policy Research. Working Paper 48. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Holloway, G.J., C.B. Barrett, and S. Ehui. 2005. "The Double Hurdle Model in the Presence of Fixed Costs." *Journal of International Agricultural Trade and Development* 1:17-28.

Key, N., E. Sadoulet, and A. de Janvry. 2000. "Transactions Costs and Agricultural Household Supply Response." *American Journal of Agricultural Economics Association* 82:245-245.

Lapar, M.L., G. Holloway, and S. Ehui. 2003. "Policy Options Promoting Market Participation of Smallholder Livestock Producers: A Case Study from the Phillipines." Socio-Economics and Policy Research Working Paper 47. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Sadoulet, E., and A. de Janvry. 1995. *Quantitative Development Policy Analysis*. Baltimore and London: The Johns Hopkins University Press.

Staal, S., C. Delgado, and C. Nicholson. 1997. "Smallholder Dairying under Transaction Costs in East Africa." *World Development* 25(5):779-94.

Zaibet, L.T., and E.G. Dunn. 1998. "Land Tenure, Farm Size and Rural Market Participation in Developing Countries: The Case of Tunisia Olive Sector." *Economic Development and Cultural Change* 46(4):831-848.

Table 1: General characteristics of agricultural households and endowments

Livestock ownership status:	Yes (N=99)		No (N=86)		Significance of the
Variables	Mean	St. dev.	Mean	St. dev.	difference
Age of the household head (years)	55.3	14.8	48.7	13.5	0.0017***
Years of schooling for household head	0.7	1.8	0.4	0.7	0.03**
Family size	10.7	3.6	7.4	3.0	0.0000***
Land size exploited (hectares)	15.8	18.4	10.2	7.1	0.009***
Distance to district Korhogo (km)	40.4	25.8	34.5	24.6	0.06*
Market price of milk (F.CFA/liter)	132	28	124	21	0.01**
Milk production (liter/month)	410	347			
Milk sales (liter/month)	323	318			
Milk consumption (liter/month)	69.4	59.3	8.2	13.6	0.0000***
Peulh tribe dummy	0.09	0.29	0.01	0.11	0.01**
Napie route dummy	0.23	0.42	0.22	0.42	0.44
Sucaf route dummy	0.12	0.33	0.13	0.34	0.42
Boundiali route dummy	0.55	0.50	0.54	0.50	0.45
Sirasso route dummy	0.16	0.37	0.13	0.34	0.1
Mbengue route dummy	0.13	0.34	0.20	0.40	0.28
Quantity of television owned	0.46	0.64	0.26	0.44	0.008***
Quantity of refrigerators owned	0.09	0.38	0.01	0.11	0.03**
Number of extension visits	3.3	12.3			
Livestock keeper salary (F.CFA/month)	12,847	4,554			
Number of local cows	9.8	8.6			
Number of crossed cows	11.7	13.8			

Note: Asterisks denotes statistical significance of the difference at ten percent level of confidence (*), five percent level of confidence (**) and one percent level of confidence(***).

Table 2a: Description of the survey variables used in Livestock ownership regression.

Variable name	Type[a]	Description
Dependent variable		
Cattle ownership	D	Dummy variable of whether or not a household owns cattle
Independent variables		
Household head age	C	Age of the household head in years
Education level of the household head	C	Number of schooling years for formal education
Television ownership	C	Number of television owned by the household
Refrigerator ownership	C	Number of refrigerators owned by the household
Land size exploited	C	Total size of land exploited by the household for farming in hectares
Market price of milk	C	Average market price in F.CFA per liter.
Distance from district Khorogo	C	Distance from agricultural households to district town in kilometers
Peulh tribe	D	Dummy variable indicating membership in the Peulh tribe
Napie route	D	Dummy variable indicating geographic location of the household
Sucaf route	D	Dummy variable indicating geographic location of the household
Boundiali route	D	Dummy variable indicating geographic location of the household
Sirasso route	D	Dummy variable indicating geographic location of the household
Mbengue route	D	Dummy variable indicating geographic location of the household

a/ "D" denotes discrete variable, "C" denotes a continuous variable.

Table 2b: Description of the survey variables used in Net Sales regression.

Variable name	Type[a]	Description
Dependent variable		
Net sales	C	Volume of milk sold in liters
Independent variables		
Household head age	C	Age of the household head in years
Family size	C	Number of people living in the household
No. of local cows	C	Number of local cows in the herd
No. of crossed bred cows	C	Number of crossed bred cows in the herd
Number of extension visits	C	Number of extension visits received by the household within a year
Land size exploited	C	Total size of land exploited by the household for farming in hectares
Livestock keeper salary	C	Wage of the hired labor in F.CFA per month
Market price of milk	C	Average market price in F.CFA per liter
Distance from district town	C	Distance from agricultural households to district town in kilometers
Napie route	D	Dummy variable indicating geographic location of the household
Sucaf route	D	Dummy variable indicating geographic location of the household
Boundiali route	D	Dummy variable indicating geographic location of the household
Sirasso route	D	Dummy variable indicating geographic location of the household
Mbengue route	D	Dummy variable indicating geographic location of the household

a/ "D" denotes discrete variable, "C" denotes a continuous variable.

Table 3: Probit Estimates of the Determinants of Cattle Ownership

Regressor	Estimates	Marginal effect
Age of the household head	0.035***	0.014
	(0.005)	(0.002)
Education level of the household head	0.108	0.043
	(0.090)	(0.035)
Television asset	0.452***	0.178
	(0.126)	(0.050)
Refrigerator asset	1.121***	0.441
	(0.389)	(0.153)
Size of the land exploited	0.014***	0.006
	(0.005)	(0.002)
Market price	0.018***	0.007
	(0.003)	(0.001)
Distance to district town	0.015***	0.006
	(0.004)	(0.002)
Peulh tribe	2.553***	0.484
	(0.543)	(0.033)
Napie route	0.356*	0.137
	(0.206)	(0.076)
Sucaf route	0.241	0.093
	(0.221)	(0.083)
Boundiali route	0.645***	0.251
	(0.217)	(0.083)
Mbengue route	-0.527**	-0.208
	(0.204)	(0.078)
Sirasso route	-0.571***	-0.225
	(0.210)	(0.080)
Intercept	-5.399***	
	(0.513)	
Number of observations	184	
N uncensored	86	
N censored	98	

Note: White's robust standard errors are reported in parentheses. Asterisks denote statistical significance at the ten percent level of confidence (*), five percent level (**), and one percent level (***). The value of the log likelihood function at the optimum is -717.1.

Table 4: Determinants of Net Sales of Milk

Regressor	Estimates	Marginal effect conditional on cattle ownership	OLS estimates w/ no sample selection
Age of the household head	3.799***	2.094	2.423*
	(1.440)	(0.728)	(1.301)
Family size	4.420	2.502	2.348
	(4.900)	(2.760)	(6.368)
Wage of the livestock keeper	-0.005*	-0.003	-0.003
	(0.003)	(0.001)	(0.003)
Number of local cows	16.259***	9.205	16.085***
	(1.526)	(0.958)	(2.016)
Number of crossed bred cows	18.250***	10.332	18.968***
	(2.128)	(1.341)	(2.767)
Market price of fresh milk	0.579	0.299	-0.781
	(0.686)	(0.460)	(0.608)
Size of the land exploited	2.139*	1.188	0.922
	(1.121)	(0.549)	(0.901)
Number of extension visits	2.572***	1.456	2.038***
	(0.821)	(0.470)	(0.746)
Distance to district town	1.129	0.615	-0.210
	(0.919)	(0.463)	(0.746)
Napie route	107.714**	66.250	86.468*
	(46.395)	(30.236)	(49.710)
Sucaf route	86.444**	53.222	56.052
	(41.545)	(26.662)	(37.329)
Boundiali route	-5.233	-2.697	-0.334
	(41.536)	(29.622)	(46.184)
Mbengue route	86.150**	31.351	109.411**
	(37.189)	(24.216)	(41.322)
Sirasso route	-71.988	-35.627	-38.519
	(47.890)	(19.374)	(49.248)
Intercept	-547.076***		-135.650
	(194.587)		(136.006)
ρ	0.899**		
	(0.136)		
λ	160.528**		
	(55.668)		

Note: White's robust standard errors are reported in parentheses. Asterisks denote statistical significance at the 10 percent (*) statistical significance at 10 percent level of confidence, five percent level (**), and one percent level (***).The value of the log likelihood function at the optimum is -717.1.