WP 2002-08

April 2002

Working Paper

Department of Applied Economics and Management
Cornell University, Ithaca, New York 14853-7801 USA

Household-Level Impacts of Dairy Cow Ownership in Coastal Kenya

Charles F. Nicholson, Philip K. Thornton and Rahab W. Muinga

Household-Level Impacts of Dairy Cow Ownership in Coastal Kenya

Charles F. Nicholson, Philip K. Thornton and Rahab W. Muinga

Abstract: Market-oriented small holder dairy production may offer opportunities for diversification from traditional export crops, particularly in light of expected rapid growth in milk consumption in the developing world. Higher-producing grade and crossbred dairy cows are a central component of efforts to promote intensification of dairy production in many developing regions, including Eastern Africa. Previous studies have identified potential positive impacts of more intensive dairying for small holder households, but few have controlled for other factors influencing the observed outcomes. This study uses reduced form censored regression models to examine the impacts of dairy cow ownership on selected outcomes for a sample of 184 households in coastal Kenya. The outcomes examined include household cash income, non-farm income, consumption of dairy products, time allocated to cattle-related tasks, number of labourers hired and total wage payments to hired labourers. The number of dairy cows owned has a large and statistically significant impact on household cash income; each cow owned increased income by 80% of the mean total income of non-adopting households. Non-farm income decreases with dairy cow ownership, indicating a substitution with alternative economic activities. Dairy cow ownership also increases consumption of dairy products by 0.6 litres per week, even though most of the increase in milk production is sold. The number of dairy cows has a significant effect on total labour for cattle-related tasks. However, in contrast to previous studies, labour allocation to cattle by household members is constant. The increase in labour required for dairy cows is met primarily by hired labourers; this is reflected in time spent by hired labourers in cattle-related tasks. However, the effects on the number of labourers hired and total payments are relatively modest, suggesting that hired labourers' time is allocated differently when dairy cows are owned. The large positive impacts on income and limited impacts on household labour allocation suggest that intensification of small holder dairying can be beneficial as a development strategy in the region if disease and feed constraints are addressed.

Charles F. Nicholson is Senior Research Associate, Department of Applied Economics and Management, Cornell University. Philip K. Thornton is Programme Leader, Systems Analysis and Impact Assessment Programme, International Livestock Research Institute, Nairobi, Kenya. Rahab W. Muinga is Director, Kenya Agricultural Research Institute Regional Research Centre, Mtwapa, Kenya. This research was supported in part by funding the Impact Assessment and Evaluation Group of the Consultative Group on International Agricultural Research (CGIAR). We also gratefully acknowledge the support and cooperation of directors and extension staff of the Kenya Ministry of Agriculture, Livestock Development and Marketing, the Central Bureau of Statistics, and the Ministry of Health. The authors thank Tom Randolph, Steve Staal, Robert Blake, Chris Barrett, and Chanjin Chung for helpful comments on previous versions of this paper.

Introduction

In many parts of Sub-Saharan Africa, small holder farmers are being compelled by policy and markets to diversify from traditional export crops, whose outlook for growth remains uncertain. Alternative agricultural activities are needed which offer higher returns to land and labour, offer the expectation of future growth, and are suitable for adoption by the resource-poor small holder farmers who continue to dominate African production (Staal *et al.*, 1997). Market-oriented dairy production may fill this need for some small holder producers, particularly in light of expected rapid growth in milk consumption in the developing world over the next two decades (Delgado *et al.*, 1999).

Intensification of small holder dairy production typically involves the adoption of a combination of cattle breeds with increased genetic potential for milk production and other complementary inputs (e.g., production of improved forages, purchased feeds, disease control measures, and improved record keeping). Previous descriptive studies have suggested that more intensive dairy production in East Africa can have positive impacts on the opportunities and welfare of small holder farmers, with consequent effects on agricultural development (Launonon *et al.*, 1985; Leegwater *et al.*, 1991). There are several potential avenues for impact. In a number of regions, there is good potential for increased demand and higher real prices for milk and dairy products. Intensification of dairy production thus can result in increased incomes for small holders. Cash receipts from milk and dairy product sales typically are distributed more evenly throughout the course of a year than income from crop sales. Less variability in cash receipts takes on particular importance given evidence from East Africa that large fluctuations in consumption can occur over relatively short periods, which suggests short-run movements in and out of poverty for a substantial number of households (Dercon and Krishnan, 2000).

Because dairy production tends to be labour intensive, it can increase the intensity of household labour use and generate hired employment. Thus, ownership of dairy cows may stimulate the demand for labour, providing benefits to unskilled labourers (who are unlikely to benefit from growth in dairy markets as cattle owners) and distributing the gains from dairy production more broadly and progressively. Cattle with European germplasm[1], either purebreds or crossed with local Zebu cattle, are the primary component of more intensive dairy production in Sub-Saharan Africa. These purebred or crossbred animals provide a vehicle for increased accumulation of productive capital. More intensive dairying also can have positive impacts on soil fertility in mixed cropping systems (Delve et al., 2001). Other potential impacts may be less favourable, including the increased demands on the labour of women and children (Mugo, 1994; Mullins et al., 1996).

Numerous previous studies have examined the use of dairy-related technologies and their impacts on small holders in Kenya. The objectives and focal points of these studies are diverse. Impact-oriented studies have examined changes in women's roles in livestock production and marketing (Price Waterhouse, 1990; Mugo, 1994; Mullins *et al*., 1996), and how more intensive dairying affects the nutritional status of households (Launonon *et al.*, 1985; Leegwater *et al.*, 1991; Huss-Ashmore, 1992). Many of these studies were motivated at least in part by the efforts of the National Dairy Development Project (NDDP), which actively promoted dairy cows and related technologies in 24 Districts in Kenya from the early 1980s to 1995. Most studies have focused on Kenya's highland areas because dairy cattle ownership is more prevalent among smallholders there. In general, these previous studies relied on tabular comparisons of key variables for households owning dairy cattle and those without them. That is, they did not control for other factors that might have affected the observed outcomes in the analysis of household-level data. Moreover, the data collected typically involved subjective judgments by households about the impacts of owning dairy cattle. Although not without value, these subjective judgments can be complemented with quantitative analyses of impacts that control for other factors influencing observed outcomes.

[1] This includes a number of cattle breeds, including Holstein, Jersey, and Brown Swiss, which originated in Europe.

The principal objective of this study is to document the impacts of ownership of cows with European germplasm (subsequently referred to as "dairy cows"[2]) on selected household-level outcomes in coastal Kenya. The decision to undertake more intensive dairying can involve changes in a variety of management practices and inputs (*e.g.*, improved forages, purchased feeds, fertilizer, and other agricultural chemicals) in addition to increases in genetic potential of the animals for milk production. The focus herein is on dairy cows because they are the central component of more intensive dairying. The use of other practices and inputs by small holders in coastal Kenya is much less frequent. The coast of Kenya is of interest because limited dairy cooperative development, higher temperatures and humidity, seasonal feed shortages, and greater disease challenges contrast with conditions in the temperate highlands. Moreover, economic development at the coast has lagged behind other regions of Kenya, and the crop yields are low compared to the highlands (Waajinberg, 1994). Household incomes are lower than in most other parts of the country, and malnutrition is a serious problem (Foeken et al., 1989**).** There is a continuing need for technologies that increase returns to agricultural production. Areas with similar climatic and dairy demand characteristics exist in Tanzania, Mozambique and Madagascar, so an understanding of the impacts of dairy cow ownership in coastal Kenya can provide insights about much of coastal East Africa.

The outcomes examined include household income, dairy product consumption, household labour allocation, and the use of hired labour. As noted above, impacts on income and consumption have been explored by numerous previous descriptive studies. However, given the importance of non-farm income in coastal Kenya, we also explore whether dairy cow ownership complements or substitutes for non-farm income sources. The influence of dairy cow ownership on household labour allocation and employment generation is less well explored in the literature. The technological package promoted by the NDDP emphasized planted forage production (based on <u>Pennisetum purpureum</u>, commonly known as Napier grass) to provide many of the nutrients required by the more productive dairy cows. However, this cut-and-carry, or "zero-grazing,"

[2] The term "dairy cows" herein refers only to purebred or crossbred cows with European germplasm, and does not include cows of local breeds that are also kept for milk production by some households in the region.

system requires more labour than the more common, semi-extensive cattle production practices (Maarse, 1997). Previous analysts have raised concerns that households would either have to reduce time devoted to other activities, or that women and children would have to work more, or both. A related issue is the extent to which dairy cow ownership generates paid employment for non-household members. Descriptive analyses suggest that households with dairy cows hire more workers and pay higher total wages, but these do not control for other factors influencing the observed outcomes (Leegwater *et al*., 1991; Nicholson *et al*., 1999). To the extent that paid employment is created, dairy cow ownership has broader developmental impact in local communities.

The Study Area

Coast province covers over 80,000 square kilometres in the southeastern part of Kenya, constituting about 15% of the country's land area. Most of the province's population of two million resides within 100 kilometres of the Indian Ocean. The coast is home to a large number of ethnic groups; an estimated two-thirds of the population are members of related ethnic groups referred to collectively as the Mijikenda. The other one-third of the province's inhabitants are migrants from Kenya's highlands. These migrant groups have a stronger tradition of keeping cattle for milk production than do the Mijikenda. Increasingly, the population of the province lives in urban areas; at present about 45% live in Mombasa and other urban centres.

The climate of the region varies with distance from the coast and the border with Tanzania, becoming drier moving inland from the ocean and from south to north. Much of the province is classified as coastal lowland (CL) zones. Rainfall in the entire area is bi-modal, with the long rains beginning around April and the short rains beginning in October. Mean annual temperatures range from 24 to 27 °C, but maximum temperatures average over 30 °C during the hottest months, January to April. The high temperatures increase the heat stress on dairy animals, reduce feed intake, decrease milk production and lengthen reproduction cycles compared to the Kenyan highlands.

Most rural households in the region engage in diverse agricultural and non-agricultural activities. Maize, cassava and cowpea are the staple foods grown in the area, although it is estimated that own-production accounts less than half of the amount of these staples consumed by most households (Leegwater *et al.*, 1991). The region is a food deficit area that imports staple foods from other parts of the country. Coconut palms and cashew trees provide cash income for many rural households. In the CL zones, cattle of local breeds are owned by about 20% of rural households (Thorpe *et al.*, 1993).

Employment off-farm has become an important income source for rural households in this area, much of it associated with the development of the tourism industry in coastal Kenya. Most studies report that about two-thirds of rural households have income from non-farm activities[3]. Leegwater *et al.* (1991) reported that one-quarter of all adults in rural households worked off-farm, with women less likely to work off-farm than men. In the study area, income from off-farm employment represented 60% of household income in the late 1980s (Foeken *et al.*, 1989; Hoorweg *et al.*, 1990). In addition to wages and salaries, many rural households operate small businesses such as water and tea kiosks. This importance of non-farm activities is common in Sub-saharan Africa and results from a variety of factors, characterized by Barrett et al. (2001) as "push" and "pull." The "push" factors include diminishing factor returns (the low-to-moderate potential of the region for intensification of agriculture in the region), risk reduction strategies, crisis management strategies, market failure, and liquidity constraints. The key "pull" factors are complementarities between activities (economies of scope) and specialization according to comparative advantage (Barrett et al., 2001). Waaijenberg (1994) asserts that the use of productivity-enhancing technologies is low due to the lack of emphasis on agricultural activities by many households.

The coast is a milk deficit area; as much as 45% of the region's dairy consumption is supplied by other parts of Kenya. In recent years shipments of pasteurised milk to the region have increased

3 As Barrett et al. (2001) note, the definitions of "farm" and "non-farm" are often inconsistently applied to assets, activities, and income across studies.

as the number of private dairy processors in Kenya has grown. The amount of milk brought to the province from elsewhere in Kenya during a year is equivalent to the production of about 20,000 small holder dairy farms. Since the price liberalisation that occurred with reform of the country's dairy policy in 1992, farm and consumer milk prices at the coast have increased relative to those in other parts of Kenya. Despite this, milk and dairy products enjoy a strong demand. Consumer surveys indicate that purchases of fresh ('raw') milk are preferred over packaged pasteurised and UHT milk (Staal and Mullins, 1996). The strong demand for milk and higher farm prices have been taken as indicators of the potential for dairy development in the region.

Although a few large and successful dairy farms have been established in the area, most milk production occurs on small holder farms. The majority of milk is produced by local Zebu breeds. Low rates of dairy cow ownership have been attributed to the susceptibility of these animals to diseases common at the coast, particularly tick-borne diseases such as East Coast fever (theileriosis), anaplasmosis, and babesiosis. Theileriosis alone results in an annual mortality rate for dairy cows of about 30% (Maloo *et al.*, 1994). Trypanosomosis carried by the tsetse fly is another important health problem for small holders, particularly in Kwale district. In addition, seasonal shortages of feed for dairy cows have been identified as a major constraint. Thus, the development of formal (commercial) milk marketing remains limited in some areas, despite the strong local demand for milk (Thorpe *et al.*, 1993).

Methods

The analysis herein is based upon the theoretical framework of the agricultural household model (Singh *et al.*, 1986). This model assumes that households maximize utility subject to constraints on cash income, time available, production technologies, and available land and capital. A reduced-form version of the model is estimated to determine the impacts of the number of dairy cows owned by the household on other variables of interest. The number of cows is assumed to predetermined for the purpose of other household decisions of interest. This assumption is based on the nature of dairy cows as a capital good, the fact that the diffusion process of the technology (Rogers, 1995) was essentially complete by the period of data collection, and empirical tests[4] supporting exogeneity. The number of dairy cows is therefore treated as an exogenous variable. Development of the reduced-form models is guided by the theoretical structure of the household model, which suggests the set of exogenous variables to be used. Let *Y* be one of the outcome variables of interest from the system of equations representing the household model above. Then, the reduced form equations for *Y* are:

$$Y = Y(Z^l, K^a, K^g, K^h, Z^d, P, W, E, DC, LC) \qquad (1)$$

where:

Y = Endogenous Impact Variable (e.g., Income, Dairy Consumption, Labour Allocation)
Z = Household characteristics (l = Locational; d = Demographic)
K = Capital Assets (a = Agricultural; g = General; h = Human Capital)
P = Price of agricultural outputs
W = Wage rate
E = Exogenous Income (e.g., remittances)
DC = Number of Dairy Cattle Owned by the household
LC = Number of Local Cattle Owned by the household

The endogenous variables of interest all have censored distributions, with the proportion of zeroes ranging from 39 to 54% of observations for variables other than household cash income. Although the number of zero observations for household cash income is small (5 of 184) estimation of the reduced-form model suggests that a censored regression is still appropriate. Thus, these reduced forms are all estimated as censored regression models. Empirical tests were conducted to determine whether to use the Tobit model formulation (Tobin, 1958) or the more flexible alternative formulation discussed by Cragg (1971). The Tobit model is specified as:

---

4 In the simultaneous equations model, a t-test of the coefficient for $\square = \square_{12} / \square_2^2$ tests whether correlation between the error terms in the two equations is zero (Greene, 1998). This test did not reject the null hypothesis of zero correlation for any of the impact variables.

$$Y_i^* = \beta' x + \varepsilon_i \,,$$
$$Y_i = 0, \text{ if } Y_i^* \leq 0$$
$$Y_i = 0, \text{ if } Y_i^* > 0.$$

The Tobit model assumes that Y^* is the solution to the utility maximization problem defined by the household model, but also conditional on Y^* being above a certain limit Y_0, a minimum threshold (McDonald and Moffit, 1980). In this case, $Y_0=0$. The Tobit model implies that the impact of a variable on the probability of a non-limit observation and the quantity observed must have the same sign.

The Cragg model relaxes this assumption, formulating these two effects as separate probit and truncated regression models, as follows:

$$\Pr[Y_i^* > 0] = \Phi(\gamma' x), \; z_i = 1 \text{ if } Y_i^* > 0$$
$$\Pr[Y_i^* \leq 0] = 1 - \Phi(\gamma' x), \; z_i = 0 \text{ if } Y_i^* \leq 0$$
$$E[Y_i \mid z_i = 1] = \beta' x + \sigma\lambda,$$

where the Tobit model is obtained if $\gamma = \beta/\sigma$. A likelihood ratio test is used to choose between these two formulations (Greene, 2000).

The equations for time spent in cattle related tasks by household member and hired labour are estimated as truncated regression models, given that under normal circumstances households must own cattle for non-zero labour allocations to be observed. All models were tested for heteroskedastic error terms using the conditional moment LM test proposed by Pagan and Vella (1989). When evidence of heteroskedasticity was present, maximum likelihood estimation was attempted assuming multiplicative heteroskedasticity of the form $\sigma_i^2 = \sigma^2 \exp\{\alpha' z_i\}$, where z is the set of variables that includes land area, number of dairy cows, age and education of household head, and district dummy variables. When estimation of truncated regression models under heteroskedasiticy did not converge, model results assuming homoskedasiticity are reported. All models were estimated using LIMDEP software (Greene, 1998).

Data

Data to estimate the models described above were collected from a sample of 198 households in three districts of Coast province (Kwale, Kilifi, and Malindi). The sampling frame was based on a census of all households in those districts owning dairy cattle. This census was conducted in early 1997 by extension agents of the Ministry of Livestock Development and Marketing (MALDM) and indicated a total of 719 households with dairy cattle. A total of 73 adopting households were selected at random from the census of 719 households. Households without dairy cattle were selected randomly from lists of 20 neighbours provided by each adopting household. The sample of households for this survey was stratified by dairy cattle ownership and division (the administrative unit below the district level; Table 1) because the divisions south and north of Mombasa differ substantially in infrastructure development and the degree of trypanosomosis challenge. A structured questionnaire was administered by MALDM extension agents in multiple visits to each household during February to April 1998. Of the 198 households surveyed, 184 were classified as small holder households. The others were expatriates or absentee owners whose principal source of income was a non-farm business located in an urban area. Of the 184 households, 77 owned no cattle, 44 owned only local cattle, and 63 owned at least one dairy cow.

The theoretical framework of the agricultural household model provides general guidelines, but the specific form of the variables included draws upon previous studies of impact in small holder agriculture (e.g., von Braun *et al*., 1989; Randolph, 1992). The literature on technology adoption suggests additional variables (Rahm and Huffman, 1984; Feder *et al*., 1985; Irungu *et al*., 1998). These exogenous variables control for influence of factors other than ownership of dairy cows, and include household location, agricultural and general capital (which also indicate wealth), human capital of the household head, members, and the individual making decisions about cattle, household demographic characteristics, prices and wages. The exogenous and endogenous variables used in the regression analyses are summarized in Table 2.

The specific variables include household locational characteristics such as distance to markets, milk purchase point, and feed purchase point. These distances were estimated by the households surveyed, and represent a measure of transactions costs in dairy production and marketing. The number of years in a current location is an indicator of the household's degree of establishment in the community, familiarity with production and marketing conditions, and may also indicate the development of social capital. Binary variables for the district in which the household is located capture differences in livestock disease challenge, off-farm employment opportunities, available infrastructure and other locational factors not specific to the household.

Agricultural capital includes the land area owned or occupied by the household and the number of agricultural implements and structures owned by the household. General capital includes wheeled carts (often used for transport), the number of vehicles owned by the household, and the number of permanent houses owned by the household. Gift and remittance income is assumed to be exogenous to the household, and is counted among the other resources available to the household. The human capital of the household is represented by characteristics of the household head such as age, sex, and years of formal education. The household head was the person identified by the survey respondent as the head of household. The household head was the survey respondent for 55% of the 184 small holder households analyzed. Participation in a previous livestock development project contributes to the household's knowledge of cattle production, and is assumed to be exogenous to the household's current production and consumption decisions. This is reasonable given that the NDDP ended three years prior to the start of the survey.

The total formal education of all resident adult household members captures the ability of the household to acquire and use new information about cattle production and marketing. Household demographic factors will also affect observed outcomes of the endogenous variables of interest. The number of months that the head was resident at the household's location during the previous 12 months may influence both production and consumption decisions. As noted previously, members of ethnic groups that migrated to the coast tend to have greater experience with cattle than the coast's traditional ethnic groups. Thus, whether the household head is a migrant is relevant to cattle ownership and management decisions. The religious affiliation of the household head may also influence outcomes of interest, as previous work has indicated that households with Muslim heads consume more milk than households whose heads have other affiliations. The age structure of the members of a household will also influence its productive activities and consumption patterns. This is represented in the econometric models by the number of adults (household members 14 years or older), the dependency ratio (total household size divided by the number of adults), and three dummy variables describing the household's stage of development as in Randolph (1992). The four stages of development include establishment, expansion, consolidation, and fission/decline. These stages are defined by the number of household members, age of the household head and the dependency ratio.

Price and wage variables include the milk price, the purchase price for maize, and an estimated maximum wage rate for the household. The milk and maize prices are those prices indicated by the household based on transactions from either of two sources: the latest transaction reported by the household during the four months prior to the survey, or, if the household did not buy or sell milk or maize during the last four months, the price at which the household believed milk or maize could be sold as of the survey date. The maximum wage rate for each household captures the potential earnings of the household in non-farm labour. To construct this variable, the daily compensation for all household members reporting non-farm income was regressed on their individual characteristics (age, education, sex, ethnic group, district of residence, and type of work; this information was collected as part of a household enumeration). The parameters from this model are used to estimate the wages that would have been earned by each household member if they had engaged in paid non-farm labour. The maximum of the individual values for each household is used to represent the wage-earning potential of each household.

The endogenous variables in the model include household cash income, non-farm cash income, dairy product consumption, labour spent in cattle-related tasks by household members and hired labour, and the number of labourers employed at the time of the survey. Information on cash income was collected based on recall information about crop production and sales, dairy and livestock product sales, income from land rental or sharing ,gift or remittance income during the prior year. Information on cash income from wage labour, salaries and business activities was based on recall information for the previous four months. Income from all sources was summed and converted to a monthly equivalent in KSh. Non-farm cash income included wages, salaries, and business income, as was also expressed as a monthly equivalent. Dairy product consumption was based on one-week recall of all dairy products consumed (fresh, pasteurized or UHT milk, and fermented milk known as mala) converted to their liquid milk equivalents. Labour spent in cattle-related tasks was constructed using a detailed one-week recall of all persons involved in ten cattle-related tasks during the previous week. The number of hired labourers and total payments to them was constructed based on recall during the previous four months.

Results

The impacts of dairy cow ownership on each variable of interest are summarized in Table 3. Because of the emphasis herein on the impact of dairy cows, complete results of the analyses are reported in separate appendix tables and the discussion of the impacts of other exogenous variables is abbreviated.

Impacts on Total and Non-farm Household Income

One of the main hypothesized impacts of dairy cow ownership is increased household income, primarily from increased milk sales. Households owning dairy cows reported significantly higher gross cash income per month (Table 2), and much of the difference between these households and those without dairy cows is due to revenues from milk sales. However, households with dairy cows also have larger landholdings and other general capital resources. Non-farm cash income is comparable among households with no cattle, only local cattle, and dairy cows (Table 2). Although it would be preferable to examine the impact on net cash income from dairy cow ownership, only limited data on input purchases were collected by the survey. However, gross cash income provides a reasonable indicator because most small holder households made only limited purchases of inputs related to dairy cows. Maize bran was the most commonly reported, with 25% of households reporting a purchase in the four months prior to the survey. These purchases accounted for less than 15% of dairy income for all small holder households.

The model of gross cash income indicates that dairy cow ownership has a statistically significant positive impact. The marginal effect of each cow is over 3,100 Kenya Shillings (KSh) per month[5], which is equivalent to about 80% of the total monthly income from all sources for households without dairy cattle (Table 2). Thus, the impact is large relative to current sources of income, and has practical as well as statistical significance. The estimated effect on income is consistent with estimates of the impact per cow on milk production and sales (not reported here) of four to five litres per day times the mean reported milk price of 26.50 KSh per litre. However, given the cost of crossbred animals of 40,000 KSh at the time of the survey, even this large effect on income implies that more than one year is required to recover the initial investment. Other variables with a statistically significant positive marginal effect on household cash income include land area, the number of wheeled carts and vehicles, sex of the household head, the number of adults in the household, and the estimated maximum wage (Appendix Table 1). Vehicle ownership has a large estimated impact on household income (only six households in the sample owned vehicles, however). Income is estimated to increase with distance from a milk or feed purchase point, which appears to be capturing the (increasing) effect of being closer to an urban center. Households located in Malindi district had significantly lower cash income than households in the other districts. The magnitude of the increase in cash income due to cow ownership is comparable to that of being a male head of household or owning a wheeled cart.

A number of similar outcomes are observed for the model of non-farm income. Ownership of dairy cows appears to substitute for non-farm economic activities engaged in by the household, as indicated by the statistically significant negative marginal effect of dairy cow numbers on non-farm income (Table 3). The magnitude of this effect is relatively small, just over 8% of the mean

[5] At the time of the data collection, 62 KSh equaled $1.00, so this is equivalent to about $50 per month or $600 per year.

total household income for households owning dairy cows. This is consistent with observations by Waaijenberg (1994) about the basic substitutability between agricultural and non-agricultural activities at the Kenya coast. Households with a greater ownership of productive agricultural assets tend to have lower non-farm income. Consistent with findings from peri-urban Tanzania (Lanjouw et al., 2001) non-farm income is positively associated with years of education of the household head, being male, and with the number of vehicles. The number of 'permanent' houses owned, the number of adult household members, and the estimated maximum wage also increase non-farm income. Similar to the household income model, distance to a milk purchase location increases non-farm income. A higher dependency ratio and fewer years of formal education for all household members are associated with higher non-farm incomes. The former may be explained by a transition process in which younger households choose to (or are forced to by limited agricultural or other assets) focus more on non-farm activities. This is consistent with the negative marginal effect of household head age. Years of education may also be capturing this transition effect, as younger households will have fewer total years of formal education. Households in Malindi district again had significantly lower non-farm incomes.

Impacts on Dairy Consumption

A large proportion of households in coastal Kenya consume milk and dairy products during a typical week. The most common form of consumption is milk in tea. Two-thirds of households surveyed reported consuming milk or dairy products during the previous week. A larger proportion of the households with dairy cows (75%) reported milk consumption. Moreover, adopting households consumed more milk on average—in total or per consumer unit—than households with no cattle or only local cattle (Table 2). The model for dairy consumption was estimated with the Cragg formulation. Ownership of dairy cows has a statistically significant marginal effect on total dairy consumption, increasing consumption of milk equivalent by 0.6 litres per week for each dairy cow owned (Table 3). This increase is double the mean household consumption of dairy products for households without dairy cows. The increase is small relative to total caloric and protein intake, but the micronutrient (e.g., Vitamin A) content of this amount of milk may have positive health benefits, particularly when the milk is fed post-weaning children (Neumann, 1998). Other factors with a positive effect on dairy consumption include residence in Malindi district, belonging to an ethnic group that migrated to the coast from the highlands, and having a Muslim head of household (Appendix Table 2). Distance to a milk purchase point and possessing a title deed were associated with lower dairy consumption. Theory predicts a negative relationship between milk price and dairy consumption, and the marginal effect in the model is negative but statistically insignificant (Appendix Table 2). This result may be explained by limits on the amount of milk that can be consumed in tea, and by the desire for generating cash income with which to purchase other staple foods. Somewhat surprisingly, household demographic characteristics appear to have little influence on dairy consumption.

Our results suggest that the majority of additional milk produced by dairy cows is sold, consistent with previous qualitative studies that reported milk for sale was a more important reason for ownership of dairy cows than having more milk for household consumption (Mugo, 1994; Launonon *et al*., 1985). This outcome is sometimes considered a negative impact, for two reasons. First, households are assumed to be selling a food with a better micronutrient bioavailability than locally available substitute foods. Second, the well-known "leakage" between income and expenditures on calories and protein may imply that household nutritional status will suffer if dairy-related income is spent on non-food items[6]. Given relative prices of milk and maize in coastal Kenya, it is often the case that households can acquire more calories and protein by selling milk and purchasing maize (Huss-Ashmore, 1992), so milk sales may be rational to achieve household nutritional objectives. Although our study did not examine household expenditures, this would be an important variable to document further the pathways by which increases in dairy-related income may improve household welfare, as in Bouis and Haddad (1990).

---

[6] Local health professionals in coastal Kenya opined that for ownership of dairy cows to achieve its full positive impact, it should be accompanied by nutritional educational programs that encourage households to consume more of the additional milk produced.

Impacts on Labour for Cattle-Related Tasks

The adoption of more intensive agricultural production practices affects household labour allocation (Chavangi and Hanssen, 1983; Dieckmann, 1994; Mullins *et al*., 1996). Dairy cows require additional labour inputs for cleaning cattle housing, cutting fodder when animals are kept in a confinement system, spraying or dipping the animals to control parasites, milking, and transporting milk to market. However, dairy in confinement systems require less labour for herding and grazing, and these tasks account for the majority of cattle-related labour at the coast. Previous work in the region, based on subjective perceptions of a small sample of households with dairy cattle, suggested that household labour for cattle care increased with ownership of dairy cattle, and that adult female household members provided most of the labour (Mullins *et al*., 1996). This raised concerns about equity in the distribution of costs and benefits of more intensive dairying, and potential negative impacts on female-dominated activities such as child care. However, previous studies did not account for the possible substitution of hired labour for household labour.

The model for total labour for cattle-related tasks uses truncated regression formulation based on data from 100 households owning cattle, although a small number of households without cattle report allocating labour to cattle care. Total labour for cattle tasks increases about six hours per week per dairy cow (Table 3). This is consistent with the labour requirements for tasks specific to dairy animals noted above. There is no corresponding increase in labour requirements for local cattle, which is consistent with the herding and tethering practices used for local cows. Distance to a feed purchase point, being a household in the "expansion" phase, being a migrant to the coast, and location in Kilifi district had large positive impacts on the total amount of the total time spent in cattle-related tasks. Younger, better educated household heads (with more younger children) imply that more total time will be devoted to cattle care. The number of plows owned decreases time spent in cattle care, indicating that households with more investment in crop-related agricultural assets will devote less time to animal agricultural activities.

Despite the increase in total labour allocated to cattle, there is no statistically significant effect—positive or negative—of dairy cows on the amount of labour allocated by household members to cattle (Table 3). The parameter estimate for dairy cows is negative but statistically insignificant (Appendix Table 3). Other factors with positive marginal effects on household labour allocated to cattle-related tasks include possession of a title deed for landholdings and being in the "expansion" stage of household development. Households at a greater distance to a milk marketing location, with older household heads, with more total education, with wheeled carts, and those in the first stage of development devote less time to cattle. The combination of an increase in labour requirements and no impact on labour by household members suggests that much of the additional labour for dairy cows is provided by labourers hired from outside the household. In contrast to Mullins *et al.* (1996), our results imply that ownership of dairy cows has relatively little impact on total labour allocation by household members[7], but suggests that it might generate secondary paid employment opportunities.

Impacts on Hired Labour

As noted above, hired labourers appear to perform many of the additional tasks required to care for dairy cattle in the study area. The use of hired labour for dairy cows can result in a number of alternative outcomes. We examine the impact of dairy cow ownership on three of these: time spent by hired labour for cattle-related tasks, total payments to hired labourers, and the number of hired labourers employed. Although only about 50% of households with dairy cows hire labourers, the average number of labourers was larger for these households than for households without dairy cattle (Table 2). Total payments to hired labourers are also substantially different for adopting and non-adopting households. However, not all of the labourers hired by households with dairy cattle perform tasks related to cattle. Because households with dairy cattle have larger amounts of land, hired labour is also assigned to tasks such as plowing and weeding. The additional time required for one dairy cow typically does not fully occupy one

[7] The results herein do not directly address the issues of changes in labour allocation among household members. However, descriptive and preliminary econometric results not reported here suggest that time spent in cattle-related tasks by women and children is not increased by dairy cow ownership.

hired labourer. Moreover, the range of observed values for the number of hired labourers is small: 90% of small holder households have two or fewer hired labourers.

The results of the previous section suggest that the time allocated by hired labour will increase due to dairy cow ownership. A truncated regression model based on data for 59 households reporting the use of hired labour for cattle-related tasks confirms this. Each dairy cow increases the time spent by hired labour close to 10 hours per week for households already allocating labour to cattle tasks[8] (Table 3). Other factors increasing the time spent by hired labour include distance to a milk purchase point (i.e., more time is required for milk marketing), the number of wheeled carts, being a migrant to the coast, and having small children. The ownership of crop-related assets (plows and grain storage) reduced the time allocated by hired labourers. Somewhat surprisingly, so did the land area the number of 'permanent' houses, and the milk price, although these latter effects were small relative to the other effects.

The number of dairy cows owned *per se* does not have a statistically significant impact on the number of hired labourers (Table 3). However, the ownership of cattle housing structures (which is strongly associated with ownership of dairy cows) has the impact of increasing the number of labourers hired. (Appendix Table 4). Moreover, the number of hired labourers is examined with the Cragg model formulation, and in the first-stage probit model the number of dairy cows is statistically significant determinant of the probability of hiring labour. Thus, there is evidence that dairy cows result in increases in the number of labourers hired. However, the importance of cattle housing structures may suggest that management factors associated with dairy cattle influence the decision to hire. Ownership of local cows does have a relatively small but significant effect on labourers hired. The number of hired labourers is also positively influenced by distance to a feed purchase point, the number of years the household has resided in the current location, possession of a title deed for landholdings, and vehicle ownership. The household's educational attainment, the number of months the head was resident, and being a Muslim increase the number of labourers hired. The ownership of grain structures and numbers

[8] Note that the impact of dairy cow ownership is larger for all households, about 14 hours per week.

of adults in the household resulted in significant decreases in the number of hired labourers employed.

Payments to hired labourers are the product of the number of labourers hired, the amount paid per labourer per day, the number of days for which they are employed, and the number of hours per day. Typically, the amount paid is expressed per day, but varies depending on the nature of the tasks performed and the number of hours worked per day. Thus, payments represent the combined effects of four elements. They are also of interest because they indicate the extent to which income generated by dairy cow ownership is distributed to households that do not own dairy cows. Analysis of payments employs the Cragg model formulation, and the results are reported for the associated truncated regression using data from 87 households who reported non-zero payments.

The marginal effect of an additional dairy cow on payments to hired labour is small but statistically significant at the 10% level. The value of 103 KSh per month represents about one and a half day's wages at wage rates reported in our survey for hired agricultural labourers. The marginal effect for all households (i.e., including those who do not currently own dairy cows) is 275 KSh, or somewhat over four days' wages (Table 3). However, as for the number of hired labourers, the ownership of cattle housing structures is associated with an increase in payments, of about nine days' wages (Appendix Table 4). This again may indicate that both certain management practices and dairy cow ownership are needed to result in increased hiring and payments. These effects of dairy cow numbers are small compared to other factors influencing payments, such as location in Malindi district, ownership of wheeled carts, being a male household head, being a Muslim household head, and being in the "expansion" stage of household development. The number of "permanent" houses owned and the number of adults in the household also influenced payments to hired labourers.

In sum, hired labourers perform much of the additional labour for dairy cattle, but the evidence is suggestive rather than definitive as to whether dairy cows in and of themselves—especially at such small scales of production—generate notable secondary employment. The strongest effect seems to be that households with and without dairy cattle allocate hired labourers' time differently when they hire labour. Households with dairy cattle will allocate a substantial portion of the labourers' time to dairy cattle care, whereas households without will allocate that time to other (non-cattle) activities.

Discussion

The results of our study in coastal Kenya suggest that ownership of dairy cows can result in positive outcomes for small holder households, notably higher incomes associated with increased milk production and sales. Impacts on household welfare may also occur through increased milk consumption despite increases in milk sales. Further, we find little evidence to support concerns about dairy cows placing additional time burdens on households. Hired labourers provide much of the additional labour required, although the empirical evidence on employment generation is less clear. Taken as a whole, these results suggest households who can successfully manage dairy cows benefit in numerous ways and experience few negative impacts. Thus, empirical evidence suggests there are benefits from efforts to promote ownership of dairy cows and improve management practices by small holder households in the region.

The substantial income-generating capacity of dairy cow ownership documented by this study suggests the need to examine further the constraints that have limited dairy cow ownership to small number of households in the region. Some previous studies of dairying at the Kenya coast (Leegwater *et al*., 1991) have suggested that only wealthier households and households with significant non-farm income could afford the investment in a dairy cow (particularly with high mortality). This is supported by the average cost of a purebred dairy cow at the time of the survey, about 40,000 KSh, or 83% of the average annual gross cash income per household. However, our data suggest that households in the bottom quartile for current ownership of various assets do, in fact, own dairy cows (Table 4). Households with small land areas and low total years of education are least likely to own dairy cows, but being in the bottom quartile *per se* does not preclude dairy cow ownership. Lack of monetary capital and other productive assets undoubtedly prevents many small holders from owning dairy cows, but further empirical exploration of this issue would help design more effective strategies to address these barriers.

Moreover, the milieu for small holder dairy production at the coast is complex. Most households have various non-farm options for generating income that may serve the same purposes, and dairying therefore represents only one of many alternatives. This is supported by the substitutability observed between dairy cattle and non-farm income sources. High mortality rates for dairy cows in the region suggest that more intensive dairying at the coast is an inherently risky activity. The high probability of losing a large investment undoubtedly limits interest in ownership of dairy cows. Some households will own dairy cows when their circumstances allow it, but these same households may temporarily cease dairying due to the death of an animal or the perception that other opportunities are more remunerative and(or) less risky.

This study focuses on household-level impacts of dairy cow ownership with only selective consideration of how complementary practices and inputs can influence these impacts. That is, our analyses examine primarily the mean response of selected outcomes to an increase in the genetic potential of cows for milk production. The results provide limited information about whether current inputs and management practices allow small holders to achieve the full potential for positive impact. Two key areas in need of further evaluation are the level European germplasm (treated essentially as a binary variable in our analyses) and management practices (e.g., feeding strategies). Previous research has identified management options and practices that are viable and can be profitable for small holders wanting to adopt more intensive dairy production (Thorpe *et al*., 1993). Additional information is needed to understand the response of dairy cows with higher genetic potential to a range of management practices and inputs. Nevertheless, the existence of management alternatives suggests that neither use nor productivity of more intensive dairying are constrained by limited availability of technological options, especially in the context of a risky production environment and competing opportunities for investment.

In terms of dairy development activities in coastal East Africa, three areas merit particular attention: mechanisms for easing access to grade and crossbred dairy cattle, either through credit schemes or through self-help small holder co-operatives, reducing the disease risks associated with dairy animals, and further research on the most appropriate levels of genetic potential for milk production and other inputs for small holders with specific characteristics. Developments in these areas would increase the propensity of small holders to go into more intensive dairying and increase the benefits for those who already own dairy cows. Whether or not such activities are viewed as worthwhile by development agencies is a question that requires a full appreciation of the opportunity costs involved and the policy goals of government.

Conclusions

The medium rainfall coastal lowlands of East Africa represent a difficult and risky production environment, yet one with access to two principal and rapidly growing urban markets, Mombasa and Dar-es-Salaam. These markets currently offer small holder dairy producers, current or potential, large margins for their milk. However, these markets and their environs also offer other opportunities for the investment of small holders' scarce capital. Many of these investment opportunities require less investment than dairy cattle, fewer specialist skills and less total labour. Nevertheless, as small holder agriculture in the coastal lowlands intensifies in response to human population pressure, dairy production and marketing, with its large potential direct financial returns and its indirect benefits for crop production, will continue to be an important enterprise (and may increase in importance) for some resource-poor families.

References

Barrett, C. B., T. Reardon, and P. Webb. 2001. Nonfarm Income Diversification and Household Livelihood Strategies in Rural Africa: Concepts, Dynamics, and Policy Implications. Food Policy. 26, 315-331.

Bouis, H. E., and Haddad, L. J. 1990. Agricultural Commercialization, Nutrition, and the Rural Poor: a Study of Philippine Farm Households. Lynne Rienner Publishers, Boulder, Colorado.

Central Bureau of Statistics. 1994. Kenya Population Census, 1989. CBS, Office of the Vice President, Ministry of Planning and National Development, Nairobi, Kenya.

Chavangi, N. A., and Hanssen, A. 1983. Women in Livestock Production, With Particular Reference to Dairying. FAO Expert Consultation on Women in Food Production and Marketing, Food and Agriculture Organisation of the UN, Rome.

Cragg, J. G. 1971. Some Statistical Models for Limited Dependent Variable with Application to Durable Goods. Econometrica. 39, 829-844.

Delgado, C., Rosegrant, M. Steinfeld, H., Ehui, S., and Courbois, C. 1999. Livestock to 2020: The Next Food Revolution. Food, Agriculture, and the Environment Discussion Paper No. 28. International Food Policy Research Institute, Food and Agriculture Organisation of the UN, and International Livestock Research Institute, Washington, DC.

Delve, R. J., Cadisch, G., Tanner, J. C., Thorpe, W. Thorne, P. and Giller, K. E. 2001. Implications of Livestock Feeding Management on Soil Fertility in the Smallholder Farming Systems of Sub-Saharan Africa. Agriculture Ecosystems and Environment. 84, 227-243.

Dercon, S. and P. Krishnan. 2000. Vulnerability, Seasonality and Poverty in Ethiopia. Journal of Development Studies. 36, 25-53

Dieckman, N. 1994. The Integration of Social and Gender Issues in Smallholder Dairy Production. World Animal Review. 79, 23-33.

Feder, G. R., Just, R. E. and Zilberman, D.. 1985. Adoption of Agricultural Innovations in Developing Countries: A Survey. Economic Development and Cultural Change. 33, 255-298.

Foeken, D., Leegwater, P., Niemeyer, R., Veermn, W. and Hoorweg, J. 1989. Seasonality in the Coastal Lowlands of Kenya. Part 3: Socio-economic Profile. Food and Nutrition Studies Programme Report 32. Nairobi/Leiden: Ministry of Planning and National Development/African Studies Centre.

Greene, W. H. 1998. LIMDEP Version 7.0 Users Manual. Plainview, NY: Econometric Software, Inc.

Greene, W. H. 2000. Econometric Analysis. (4th ed.) Upper Saddle River, NJ: Prentice Hall.

Hoorweg, J., Niemeyer, R. and van W Steenbergen, W. M. 1990. Economic and Nutritional Conditions at Settlement Schemes in Coast Province, Kenya. Food and Nutrition Studies Programme Draft Report. Nairobi/Leiden: Ministry of Planning and National Development/African Studies Centre.

Huss-Ashmore, R. 1992. Nutritional Impacts of Intensified Dairy Production: an Assessment in Coast Province, Kenya. International Laboratory for Research on Animal Diseases Technical Report No. 1. Nairobi: ILRAD.

Irungu, P., Mbogoh, S. G., Staal, S. J. and Njubi, D. 1998. Factors Influencing the Adoption of Napier Grass in Smallholder Dairying in the Highlands of Kenya. In Food, Lands and Livelihoods. Setting Research Agendas for Animal Science. Proceedings of BSAS/KARI/APSK/ILRI International Conference, 27-30 January 1998. British Society of Animal Science, Penicuik, Midlothian, Scotland.

Lanjouw, P., J. Quizon, and R. Sparrow. 2001. Non-Agricultural Earnings in Peri-Urban Areas of Tanzania: Evidence from Household Survey Data. Food Policy. 26, 385-403.

Launonon, R., Karinpää, A., Marangu, L. and Minae, S. 1985. Rural Dairy Development in Meru: A Socio-Economic Study of Small holder Milk Production, Consumption, and Marketing. Report 8/1985 B, Institute of Development Studies, University of Helsinki, Helsinki, Finland.

Leegwater, P., Ngolo, J. and Hoorweg, J. 1991. Dairy Development and Nutrition in Kilifi District, Kenya. Food and Nutrition Studies Programme, Report No. 35. Nairobi, Kenya: Food and Nutrition Planning Unit, Ministry of Planning and National Development; Leiden, Netherlands: African Studies Center.

Maarse, L. M. 1997. Process of Change in Dairy Husbandry Extension: The Case of Coastal Kenya. MSc Thesis, Larenstein International Agricultural College and University of Reading, Deventer, Netherlands, and Reading, UK.

MacDonald, J. F., and Moffit, R. A. 1980. The Uses of Tobit Analysis. Review of Economics and Statistics. 62, 318-321.

Maloo, S.H., Thorpe, W., Perry, B.D. and Ngumi, P.N. 1994. Systematic epidemiological studies to identify and resolve health constraints to smallholder dairy production in coastal lowland Kenya. In: Proceedings of the 7th International Symposium on Veterinary Epidemiology and Economics ISVEE, Nairobi, Kenya. The Kenyan Veterinarian. 18, 359-361.

Mugo, P. W. 1994. A Gender Differentiated Study on Impacts of Intensive Dairy Farming on Socio-economic Position of Small holder Households in Meru District, Kenya. Ministry of Agriculture, Livestock Development, and Marketing. National Dairy Development Project. Nairobi, Kenya.

Mullins, G., Wahome, L., Tsangari, P. and Maarse, L. 1996. Impacts of Intensive Dairy Production on Small holder Farm Women in Coastal Kenya. Human Ecology. 242, 231-253.

Neumann, C. G. 1998. Role of Animal Source Foods in Improving Diet Quality and Micronutrient Content and Contribution to Child Health, Growth, and Development. Symposium on Human Nutrition and Livestock in the Developing World, October 14, 1998. Little Rock, Arkansas: Heifer Project International.

Nicholson, C. F., Thornton, P. K., Mohammed, L., Muinga, R. W., Mwamachi, D. H., Elbasha, E. H., Staal, S. J. and W. Thorpe. 1999. Small holder Dairy Technology in Coastal Kenya. An Adoption and Impact Study. ILRI Impact Assessment Series 5, International Livestock Research Institute, Nairobi, Kenya.

Pagan, A. and F. Vella. 1989. Diagnostic Test for Model Based on Individual Data: A Survey. Journal of Applied Econometrics, 4, 29-59.

Price Waterhouse. 1990. The Role of Women in the National Dairy Development Programme, Kenya. Nairobi, Kenya.

Rahm, M. R. and Huffman, W. E. 1984. The Adoption of Reduced Tillage: The Role of Human Capital and Other Variables. American Journal of Agricultural Economics. 66, 405-413.

Randolph, T.F. 1992. The Impact of Commercialization on Child Nutrition: A Case Study of Small holder Households in Malawi. Ph.D. dissertation, Cornell University, Ithaca, NY.

Rogers, E. M. 1995. Diffusion of Innovations. (4th ed.) New York: The Free Press.

Singh, I., Squire, L. and Strauss, J. (eds.) 1986. Agricultural Household Models : Extensions, Applications, and Policy. Johns Hopkins University Press, Baltimore, Maryland.

Staal, S. J., Delgado, C., and Nicholson, C. 1997. Smallholder Dairying Under Transactions Costs in East Africa. World Development. 25, 779-794.

Staal, S.J. and Mullins, G. 1996. Dairy Consumption and its Determinants in Coastal Kenya. KARI/ILRI Collaborative Research Report, International Livestock Research Institute, Nairobi, Kenya.

Thorpe, W., Chabari, F., Maloo, S., Muinga, R., Mukhebi, A., Mullins, G., Mureithi, J., Mussukuya, E., Nyambaka, R., ole Make, M., Otieno, L., Perry, B., Rugema, E. and Wekesa, E. 1993. Small holder dairy cattle production in coastal Kenya; Resource base assessment and constraint identification. In: "Animal Production in Developing Countries", Proceedings of the meeting held 2-4 Sept. 1991, at Ashford, U.K. British Society of Animal Production, Penicuik, Scotland, U.K. pp. 167-168.

Tobin, J. 1958. Estimation of Relationships for Limited Dependent Variables. Econometrica, 26: 24-36.

Waaijenberg, H. 1994. Mijikenda Agriculture in Coast Province of Kenya: Peasants in Between Tradition, Ecology, and Policy. Royal Tropical Institute, Wageningen, The Netherlands.

von Braun, J., Puetz, D. and Webb, P. 1989. Irrigation Technology and Commercialization of Rice in Gambia: Effects on Income and Nutrition. IFPRI Research Report No. 75, International Food Policy Research Institute, Washington, DC.

Table 1. Total Households and Number of Survey Respondents by Ownership of Dairy Cattle and Administrative Division

District	Division	Total House-holds[1]	Households with Dairy Cattle[2]	% With Dairy Cattle	Surveyed Households: With Dairy Cattle	Surveyed Households: Without Dairy Cattle	Surveyed Households: Total
Kwale	Matuga	11,010	53	0.48	6	12	18
	Kubo	6,434	20	0.31	2	9	11
	Mswambweni	30,272	73	0.24	8	38	46
Kilifi	Kaloleni	26,167	115	0.44	12	29	41
	Bahari	23,250	274	1.18	24	12	36
Malindi	Malindi	30,243	184	0.61	21	25	46
Total		127,376	719	0.56	73	125	198

[1] Central Bureau of Statistics, 1994.
[2] Census of households with dairy cattle, Ministry of Agriculture, Livestock Development and Marketing, 1997.

Table 2. Household Characteristics[1] and Variables Used in Econometric Analyses, by Cattle Ownership Status

Variable	Cattle Ownership Status			
	Without Dairy Cattle			Own Dairy Cattle N=63
	Own No Cattle N=77	Own Local Cattle N=44	Total N=121	
Exogenous Variables				
Household Locational Characteristics				
Distance to closest market, km	3.50	2.96	3.30	3.97
	(3.83)	(2.06)	(3.28)	(5.15)
Distance to closest milk purchase point, km	1.94	2.78	2.25	3.29
	(2.54)	(2.23)	(2.45)	(4.78)
Distance to feed purchase point, km	27.86	13.98	22.64	11.75
	(23.98)	(20.55)	(23.64)	(16.86)
Number of years in current location	29.42	28.93	29.24	27.06
	(18.97)	(11.37)	(16.54)	(13.01)
District dummy (1=Kilifi District, 0 Otherwise)	0.47	0.61	0.52	0.75
	–	–	–	–
District dummy (1=Malindi District, 0 Otherwise)	0.04	0.50	0.21	0.30
	–	–	–	–
Agricultural Capital				
Land area owned or occupied, acres	8.14	11.05	9.20	18.27
	(12.41)	(6.87)	(10.79)	(25.72)
Tenure status of lands occupied by household	0.58	0.84	0.68	0.86
(1=Title deed; 0=Informal)	–	–	–	–
Number of plows owned	1.60	1.23	1.46	0.65
	(2.26)	(2.14)	(2.21)	(1.22)
Number of cattle housing structures owned	0.01	0.14	0.06	0.59
	(0.11)	(0.35)	(0.23)	(0.50)
Number of grain storage structures owned	0.40	0.20	0.33	0.32
	(0.54)	(0.41)	(0.51)	(0.47)
General Capital and Resources				
Number of wheeled carts owned	0.01	0.09	0.04	0.17
	(0.11)	(0.29)	(0.20)	(0.38)
Number of vehicles owned	0.03	0.00	0.02	0.08
	(0.16)	0.00	(0.13)	(0.33)
Number of 'permanent' houses owned	0.12	0.34	0.20	0.59
	(0.40)	(0.81)	(0.59)	(1.03)
Gift and Remittance Income, KSh/month	155.38	35.74	111.87	286.39
	(675.18)	(127.95)	(545.82)	(734.05)
Household Human Capital				
Age of household head, years	55.28	53.40	54.59	53.47
	(13.16)	(13.96)	(13.43)	(12.31)
Sex of household head (1=Male; 0=Female)	0.94	0.89	0.92	0.95
	–	–	–	–

Variable	Cattle Ownership Status			
	Without Dairy Cattle			Own Dairy Cattle N=63
	Own No Cattle N=77	Own Local Cattle N=44	Total N=121	
Education of household head, years	4.86	4.16	4.60	7.30
	(4.50)	(4.03)	(4.33)	(4.74)
Participation in any livestock development project (1=Yes; 0=No)	0.21	0.12	0.18	0.51
	–	–	–	–
Total formal education for adult household members, years	7.41	6.79	7.18	9.92
	(5.29)	(3.45)	(4.69)	(9.66)
Household Demographic Characteristics				
Number of months household head resident in past year	11.58	11.33	11.49	11.40
	(1.91)	(2.51)	(2.14)	(2.39)
Is household head a migrant to Coast? (1=Yes; 0=No)	0.14	0.25	0.18	0.21
	–	–	–	–
Number of persons > 14 years old in household	4.90	6.55	5.50	6.24
	(2.57)	(3.55)	(3.06)	(3.39)
Dependency ratio = Household size / number of adults	1.87	1.64	1.78	1.82
	(0.81)	(0.77)	(0.80)	(2.03)
Religion of household head dummy (1=Muslim; 0=Other)	0.38	0.16	0.30	0.17
	–	–	–	–
Household stage of development dummy (1=Establishment, 0 Otherwise)	0.88	0.86	0.88	0.83
	–	–	–	–
Household stage of development dummy (1=Expansion, 0 Otherwise)	0.69	0.82	0.74	0.79
	–	–	–	–
Household stage of development dummy (1= Consolidation, 0 Otherwise)	0.34	0.34	0.34	0.25
	–	–	–	–
Number of children less than 6 years	1.32	1.16	1.26	1.19
	(1.50)	(1.95)	(1.67)	(1.59)
Prices and Wages				
Milk price, KSh/litre	31.30	31.03	31.20	26.50
	(11.14)	(7.43)	(9.92)	(7.57)
Purchase price of maize, KSh/kg	13.98	18.14	15.49	19.11
	(3.95)	(5.40)	(4.94)	(9.22)
Maximum of estimated wage for household members, KSh/day	177.90	161.34	171.88	242.84
	(190.08)	(169.64)	(182.37)	(595.85)
Cow Ownership		-	–	
Number of dairy cows	0.00	0.00	0.00	2.43
	–	–	–	(5.23)
Number of local cows	0.00	1.77	0.64	1.21
	–	(1.87)	(1.40)	(3.18)
Endogenous Variables				
Milk Production				
Milk production, litres/month	0.00	36.83	10.32	361.70
	0.00	(59.95)	(35.49)	(816.87)

Variable	Cattle Ownership Status			
	Without Dairy Cattle			Own Dairy Cattle N=63
	Own No Cattle N=77	Own Local Cattle N=44	Total N=121	
Income and Income Sources				
Total non-farm cash income, KSh/mo	2,906	2,344	2,701	3,204
	(4,006)	(4,800)	(4,300)	(5,993)
Total Cash HH income, KSh/mo	3,841	4,299	4,007	12,764
	(4,996)	(5,095)	(5,016)	(25,155)
Dairy Product Consumption				
Milk equivalent consumption per consumer unit, litres/week	0.49	0.90	0.63	1.96
	(0.66)	(1.54)	(1.07)	(2.17)
Milk equivalents consumed, litres/week	2.11	4.41	2.93	9.03
	(2.34)	(5.32)	(3.84)	(10.57)
Labour Allocation				
Total cattle labour, minutes/week	3.12	3,381.52	1,195.50	4,781.35
	(19.21)	(2,210.71)	(2,080.15)	(3,131.38)
Cattle labour by HH members, minutes/week	1.56	2,471.34	899.66	2,059.40
	(13.68)	(2,432.59)	(1,882.51)	(1,956.54)
Cattle labour by Hired labourers, minutes/week	1.50	812.33	293.40	3,682.78
	(13.42)	(1,471.91)	959.99	(5,458.48)
Employment Generation				
Total payments to hired labourers, KSh/mo	183	164	176	1,163
	(470)	(411)	(448)	(1,697)
Total hired labourers	0.64	0.36	0.54	1.52
	(1.10)	(0.69)	(0.98)	(1.61)

[1] Mean values for sample households. Standard deviations in parentheses.

Table 3. Estimated Coefficients and Marginal Effects on Impact Variables for Number of Dairy Cows Owned

Model Characteristic	Total Household Cash Income, KSh/month	Non-farm Household Cash Income, KSh/month	Dairy Consumption, litres/week[1]	Total Labour for Cattle-Related Tasks, minutes/week	Household Labour for Cattle-Related Tasks, minutes/week	Hired Labour for Cattle-Related Tasks, minutes/week	Payments to Hired Labour, KSh/month[1]	Number of Hired Labourers[1]
Regression Coefficient	3,375.50	-1,172.33	2.30	478.00	-224.40	845.00	275.70	-0.07
Standard error	270.40	555.92	0.80	181.70	208.80	296.80	151.00	0.10
t-statistic	12.48	-2.109	2.94	2.63	-1.08	2.85	1.83	-0.68
Probability	0.00	0.04	0.00	0.01	0.28	0.00	0.07	0.50
Marginal Effect	3,120.75	-1,106.05	1.61	367.52	-116.78	589.24	103.96	-0.06
Standard error	255.50	535.14	0.60	139.70	108.60	207.00	57.00	0.08
t-statistic	12.22	-2.06	2.60	2.63	-1.08	2.85	1.83	-0.68
Probability	0.00	0.04	0.01	0.01	0.28	0.00	0.07	0.50
Model formulation	Tobit	Tobit w/Het[2]	Cragg[3]	Truncated[4]	Truncated[4]	Truncated[4]	Cragg[3]	Cragg[3]
Number of observations	170	170	168	100	87	59	71	77
Adjusted R^2 (OLS)	0.88	0.44	0.28	0.24	-0.39	-0.39	0.50	0.23
Log-likelihood	-1644.2	-983.35	-409.5	-885.7	-736.9	-502.2	-532.5	-89.6

Note: Additional model results are presented in Appendix Tables 1 through 4.

1 Reported results are for the truncated regression model.

2 Tobit model with heteroskedasticity of the form $\_{i}^{2} = \_^{2}\_\exp\{\_'z_i\}$, where z is the set of variables that includes total years of education of adult household members and district dummy where 1 = Kilifi District.

3 The formulation of Cragg (1971) involves sequential estimation of probit and truncated regression models, which allows for the direction of impact of X on Prob[Y*<0] to differ from the direction of impact of X on E[Y|Y*>0|X].

4 Truncated regression model is used because households without cattle report no labour for cattle-related tasks.

Table 4. Dairy Cow Ownership by Resource and Non-farm Income Quartile

Asset or Income Category	Bottom Quartile[1]		Top Quartile[2]	
	Upper Limit[3]	% with dairy cows	Lower limit[4]	% with dairy cows
Land area, ha	4.0	17.4%	12.0	52.2%
Plows owned[5]	0.0	46.7%	2.0	19.6%
Grain storage buildings owned	0.0	34.8%	1.0	34.8%
Local cows owned	0.0	26.1%	1.0	41.3%
Adults in household	8.0	30.4%	11.0	39.1%
Education of household, years	19.5	15.2%	62.0	47.8%
Maximum wage, KSh/day	95.8	34.7%	173.8	37.0%
Non-farm income, KSh/month	0.0	41.3%	3,270.0	37.0%

Note: N=184 small holder households, 46 households per quartile, unless otherwise noted.

1 Households in the lowest 25% of households surveyed for the indicated asset or income category.

2 Households in the top 25% of households surveyed for the indicated asset or income category.

3 Maximum observed value of the indicated asset or income category for households in the bottom quartile.

4 Minimum observed value of the indicated asset or income category for households in the top quartile.

5 N=45 households in bottom quartile.

Appendix Table 1. Marginal Effects in Models of Total and Non-farm Household Income

Variable or Model Summary Characteristic	Total Cash Income, KSh/month		Non-farm Cash Income, KSh/month	
	Marginal effect	t-stat	Marginal effect	t-stat
Constant	402.87	0.06	2,896.59	0.32
Distance to closest market, km	-131.98	-1.26	2.81	0.01
Distance to closest milk purchase point, km	624.57	5.01	347.69	2.20
Distance to feed purchase point, km	61.05	2.90	29.48	1.39
Number of years in current location	47.24	1.51	52.29	0.96
District dummy (1=Kilifi District, 0 Otherwise)	-2,338.98	-1.45	-385.78	-0.17
District dummy (1=Malindi District, 0 Otherwise)	-3,304.78	-2.37	-6,343.33	-2.06
Land area owned or occupied, acres	95.46	2.45	81.36	1.19
Tenure status (1=Title deed; 0=Informal)	1,320.46	1.29	1,576.99	1.03
Number of plows owned	-406.25	-1.69	-426.37	-1.09
Number of cattle housing structures owned	481.63	0.43	599.36	0.42
Number of grain storage structures owned	-498.34	-0.54	-842.31	-0.54
Number of wheeled carts owned	3,837.19	2.21	3,105.76	1.14
Number of vehicles owned	9,712.34	4.13	10,699.59	4.09
Number of 'permanent' houses owned	578.65	0.86	2,018.85	2.53
Gift and Remittance Income, KSh/month	-0.26	-0.36	-0.96	-0.85
Age of household head, years	-333.93	-1.44	-253.04	-0.80
Age of household head squared, years	2.89	1.41	2.90	1.06
Sex of household head (1=Male; 0=Female)	3,351.35	2.19	3,127.70	1.55
Education of household head, years	231.20	1.62	482.12	2.03
Participation in livestock project (1=Yes; 0=No)	-1,282.86	-1.41	-1,072.40	-1.01
Formal education for adult household members, years	-291.24	-1.57	-725.59	-2.06
(Formal education for adult household members)^2 years	1.75	0.58	3.39	0.86
Number of months household head resident in past year	-30.78	-0.17	-459.61	-2.54
Is household head a migrant to Coast? (1=Yes; 0=No)	-1,425.39	-0.94	-2,402.10	-1.11
Number of persons > 14 years old in household	617.45	2.80	791.63	1.66
Dependency ratio = Household size / number of adults	1,003.25	1.06	3,125.45	2.21
Religion of household head (1=Muslim; 0=Other)	985.90	0.72	36.25	0.02
Household stage of development (1=Establishment, 0 Otherwise)	-343.75	-0.18	-3,484.85	-1.54
Household stage of development (1=Expansion, 0 Otherwise)	349.98	0.21	-242.21	-0.09
Household stage of development (1=Consolidation, 0 Otherwise)	-1,989.90	-1.50	1,216.86	0.66
Number of children less than 6 years old	-330.65	-1.03	-510.69	-0.84
Milk price, KSh/litre	47.32	1.11	-9.97	-0.19
Purchase price of maize, KSh/kg	-13.96	-0.20	74.36	0.63
Maximum estimated wage, KSh/day	6.75	6.54	5.85	3.73
Number of dairy cows owned	3,120.75	12.22	-1,106.05	-2.07
Number of local cows owned	-155.88	-0.60	-344.95	-0.62
Model Characteristics				
Model formulation	Tobit		Het Tobit[1]	
Number of observations	170		170	
Adjusted R^2 (OLS)	0.88		0.44	
Log-likelihood	-1644.2		-983.35	
Test for heteroskedasticity[2]				
LM statistics	0.54		36.63	
Probability	0.46		0.00	
Test of Specification for Prob[Y*<0][3]				

LR statistic	[4]		[4]	
Probability	[4]		[4]	

[1] Tobit model with heteroskedasticity of the form _i = __exp{_’z), where z is the set of exogenous variables that includes total education of adult household members and district dummy where 1 = Kilifi.

[2] Conditional moment test using LM statistic (Pagan and Vella, 1989).

[3] Likelihood test using log-L values from Tobit, probit and truncated regression models (Greene, 2000).

[4] Not reported because probit model not feasible or truncated regression model would not converge.

Appendix Table 2. Marginal Effects in Models of Dairy Consumption and Total Labour for Cattle-related Tasks

Variable or Model Summary Characteristic	Dairy Consumption, litres/week		Total Labour for Cattle Tasks, min/week	
	Marginal effect	t-stat	Marginal effect	t-stat
Constant	4.82	0.42	8,574.42	1.59
Distance to closest market, km	0.10	0.49	-90.14	-1.27
Distance to closest milk purchase point, km	-0.26	-1.74	34.23	0.47
Distance to feed purchase point, km	0.02	0.73	29.91	1.70
Number of years in current location	-0.02	-0.37	26.67	1.09
District dummy (1=Kilifi District, 0 Otherwise)	1.67	0.88	2,122.50	1.89
District dummy (1=Malindi District, 0 Otherwise)	5.31	2.50	389.29	0.49
Land area owned or occupied, acres	0.04	0.97	-35.50	-1.50
Tenure status (1=Title deed; 0=Informal)	-2.74	-1.82	809.76	0.99
Number of plows owned	-0.11	-0.29	-404.10	-1.72
Number of cattle housing structures owned	1.85	1.37	83.35	0.13
Number of grain storage structures owned	0.15	0.13	-744.34	-1.10
Number of wheeled carts owned	-0.35	-0.18	153.40	0.17
Number of vehicles owned	-6.28	-1.61	1,582.44	1.14
Number of 'permanent' houses owned	-0.75	-0.87	-761.96	-1.62
Gift and Remittance Income, KSh/month	0.00	0.05	0.15	0.30
Age of household head, years	-0.19	-0.54	-295.98	-1.65
Age of household head squared, years	0.00	0.68	2.64	1.64
Sex of household head (1=Male; 0=Female)	-0.35	-0.18	-335.53	-0.32
Education of household head, years	-0.13	-0.67	277.04	2.89
Participation in livestock project (1=Yes; 0=No)	1.31	1.07	489.95	0.84
Formal education for adult household members, years	0.25	0.38	-307.77	-2.09
$(\text{Formal education for adult household members})^2$ years	0.00	0.12	2.63	1.33
Number of months household head resident in past year	-0.09	-0.43	73.55	0.71
Is household head a migrant to Coast? (1=Yes; 0=No)	4.08	2.46	2,381.87	2.45
Number of persons > 14 years old in household	0.11	0.37	-373.91	-2.73
Dependency ratio = Household size / number of adults	-0.14	-0.07	276.19	0.39
Religion of household head (1=Muslim; 0=Other)	4.24	2.41	52.79	0.06
Household stage of development (1=Establishment, 0 Otherwise)	-4.22	-1.29	-3,350.64	-2.10
Household stage of development (1=Expansion, 0 Otherwise)	1.29	0.41	4,781.93	3.33
Household stage of development (1=Consolidation, 0 Otherwise)	-1.22	-0.62	-1,389.65	-1.78
Number of children < 6 years old	-0.12	-0.28	592.83	3.12
Milk price, KSh/litre	-0.10	-1.39	-41.15	-1.09
Purchase price of maize, KSh/kg	0.03	0.25	36.56	1.02
Maximum estimated wage, KSh/day	0.00	0.69	0.04	0.09
Number of dairy cows owned	0.63	2.14	367.52	2.63
Number of local cows owned	-0.30	-1.01	-74.83	-0.50
Model Characteristics				
Model formulation	Cragg[1]		Truncated[2]	
Number of observations	112		100	
Adjusted R^2 (OLS)	0.26		0.24	
Log-likelihood	-309.4		-885.7	
Pagan Vella test for heteroskedasticity[3]				
LM statistics	6.71		14.74	

Variable or Model Summary Characteristic	Dairy Consumption, litres/week		Total Labour for Cattle Tasks, min/week	
Probability	0.03		0.01	
Test of Specification for Prob[Y*<0][4]				
LR statistic	69.89		[5]	
Probability	0.00		[5]	

[1] The formulation of Cragg (1971) involves sequential estimation of probit and truncated regression models, which allows for the direction of impact of X on Prob[Y*<0] to differ from the direction of impact of X on E[Y|Y*>0|X]. Reported results are for the truncated regression. Although tests indicate presence heteroskedastic errors, heteroskedastic truncated models would not converge.

[2] Truncated regression model used because households without cattle report little labour for cattle-related tasks. Although tests indicate presence heteroskedastic errors, heteroskedastic truncated models would not converge.

[3] Conditional moment test using LM statistic (Pagan and Vella, 1989).

[4] Likelihood test using log-L values from Tobit, probit and truncated regression models (Greene, 2000).

5 Not tested for this model formulation.

Appendix Table 3. Marginal Effects in Models of Household and Hired Labour for Cattle-Related Tasks

Variable or Model Summary Characteristic	Household Time in Cattle Tasks, min/week		Hired Labour Time in Cattle Tasks, min/week	
	Marginal effect	t-stat	Marginal effect	t-stat
Constant	6,590.09	1.48	1,832.42	0.24
Distance to closest market, km	-117.30	-1.77	428.52	2.33
Distance to closest milk purchase point, km	11.19	0.20	-141.65	-1.14
Distance to feed purchase point, km	14.17	1.15	11.54	0.42
Number of years in current location	18.97	0.83	44.30	1.24
District dummy (1=Kilifi District, 0 Otherwise)	1,631.57	1.63	26.67	0.02
District dummy (1=Malindi District, 0 Otherwise)	-411.74	-0.70	455.30	0.45
Land area owned or occupied, acres	20.56	1.21	-77.61	-2.07
Tenure status (1=Title deed; 0=Informal)	1,360.80	1.98	-642.49	-0.62
Number of plows owned	-79.27	-0.58	-754.62	-2.56
Number of cattle housing structures owned	500.70	1.01	688.74	0.73
Number of grain storage structures owned	-653.12	-1.21	-2,781.95	-2.48
Number of wheeled carts owned	-1,991.95	-2.38	2,192.64	1.97
Number of vehicles owned	1,543.31	1.19	816.78	0.52
Number of 'permanent' houses owned	-60.85	-0.19	-1,663.99	-2.77
Gift and Remittance Income, KSh/month	-0.08	-0.19	0.29	0.52
Age of household head, years	-243.37	-1.69	28.72	0.11
Age of household head squared, years	2.01	1.59	-0.17	-0.07
Sex of household head (1=Male; 0=Female)	-1,336.59	-1.62	137.90	0.11
Education of household head, years	27.35	0.40	206.39	1.43
Participation in livestock project (1=Yes; 0=No)	-521.17	-1.19	-116.87	-0.15
Formal education for adult household members, years	-188.28	-1.86	-52.30	-0.21
(Formal education for adult household members)^2 years	0.66	0.47	2.47	0.92
Number of months household head resident in past year	136.44	1.20	31.85	0.25
Is household head a migrant to Coast? (1=Yes; 0=No)	612.59	0.72	1,787.61	1.80
Number of persons > 14 years old in household	-156.73	-1.72	-185.67	-0.95
Dependency ratio = Household size / number of adults	541.43	1.00	-1,002.33	-1.03
Religion of household head (1=Muslim; 0=Other)	-1,221.18	-1.69	2,171.34	1.76
Household stage of development (1=Establishment, 0 Otherwise)	-4,935.41	-2.71	1,849.68	0.88
Household stage of development (1=Expansion, 0 Otherwise)	5,343.60	2.91	-972.42	-0.57
Household stage of development (1=Consolidation, 0 Otherwise)	-830.17	-1.31	-74.78	-0.07
Number of children < 6 years old	59.84	0.45	597.44	1.79
Milk price, KSh/litre	-0.73	-0.03	-132.08	-2.86
Purchase price of maize, KSh/kg	10.73	0.34	46.99	1.03
Maximum estimated wage, KSh/day	-0.21	-0.48	0.97	1.62
Number of dairy cows owned	-116.78	-1.08	589.24	2.85
Number of local cows owned	20.18	0.19	-52.35	-0.25
Model Characteristics				
Model formulation	Truncated[1]		Truncated[1]	
Number of observations	87		59	
Adjusted R^2 (OLS)	-0.39		-0.39	
Log-likelihood	-736.9		-502.2	
Test for heteroskedasticity[2]				
LM statistics	24.42		48.47	

Variable or Model Summary Characteristic	Household Time in Cattle Tasks, min/week		Hired Labour Time in Cattle Tasks, min/week	
Probability	0.00		0.00	
Test of Specification for Prob[Y*<0][3]				
LR statistic	[4]		[4]	
Probability	[4]		[4]	

[1] Truncated regression model used because households without cattle report little labour for cattle-related tasks. Although tests indicate presence heteroskedastic errors, heteroskedastic truncated models would not converge.

[2] Conditional moment test using LM statistic (Pagan and Vella, 1989).

[3] Likelihood test using log-L values from Tobit, probit and truncated regression models (Greene, 2000).

[4] Not tested for this model formulation.

Appendix Table 4. Marginal Effects in Models of Number of Hired Labourers and Payments to Hired Labour

Variable or Model Summary Characteristic	Number of Hired Labourers		Payments to Hired Labour, KSh/month	
	Marginal effect	t-stat	Marginal effect	t-stat
Constant	-0.46	-0.13	-867.18	-0.34
Distance to closest market, km	0.06	1.19	57.00	1.28
Distance to closest milk purchase point, km	0.05	1.50	-38.79	-1.16
Distance to feed purchase point, km	0.03	3.87	1.92	0.31
Number of years in current location	0.03	2.55	7.83	0.81
District dummy (1=Kilifi District, 0 Otherwise)	0.64	1.15	65.35	0.16
District dummy (1=Malindi District, 0 Otherwise)	-0.16	-0.33	1,395.81	3.77
Land area owned or occupied, acres	0.00	-0.22	-10.39	-1.28
Tenure status (1=Title deed; 0=Informal)	1.09	2.70	80.47	0.24
Number of plows owned	0.07	0.84	56.35	1.02
Number of cattle housing structures owned	0.67	1.85	533.70	2.15
Number of grain storage structures owned	-1.11	-2.87	-458.52	-1.58
Number of wheeled carts owned	0.35	0.64	-780.35	-1.80
Number of vehicles owned	2.01	2.82	247.82	0.49
Number of 'permanent' houses owned	-0.07	-0.25	385.02	1.84
Gift and Remittance Income, KSh/month	0.00	0.39	0.44	3.26
Age of household head, years	-0.09	-0.90	-118.60	-1.65
Age of household head squared, years	0.00	1.38	1.43	2.36
Sex of household head (1=Male; 0=Female)	0.20	0.40	1,085.50	3.13
Education of household head, years	0.05	0.78	100.34	2.09
Participation in livestock project (1=Yes; 0=No)	-0.25	-0.91	-97.01	-0.39
Formal education for adult household members, years	0.27	1.70	193.58	1.73
(Formal education for adult household members)^2 years	-0.02	-2.24	-13.60	-2.36
Number of months household head resident in past year	0.12	2.07	44.10	1.13
Is household head a migrant to Coast? (1=Yes; 0=No)	0.26	0.62	432.31	1.25
Number of persons > 14 years old in household	-0.25	-2.79	-297.29	-4.33
Dependency ratio = Household size / number of adults	-0.38	-0.81	1.38	0.00
Religion of household head (1=Muslim; 0=Other)	1.40	3.05	1,100.23	3.01
Household stage of development (1=Establishment, 0 Otherwise)	0.78	0.95	-185.16	-0.30
Household stage of development (1=Expansion, 0 Otherwise)	-0.30	-0.46	1,267.60	2.67
Household stage of development (1=Consolidation, 0 Otherwise)	-0.70	-1.40	-539.59	-1.51
Number of children < 6 years old	-0.07	-0.49	160.70	1.47
Milk price, KSh/litre	-0.06	-3.57	-20.23	-1.65
Purchase price of maize, KSh/kg	0.04	1.70	-9.87	-0.72
Maximum estimated wage, KSh/day	0.00	3.17	0.42	2.73
Number of dairy cows owned	-0.06	-0.68	103.96	1.83
Number of local cows owned	0.14	1.67	5.99	0.10
Model Characteristics				
Model formulation	Cragg[1]		Cragg[1]	
Number of observations	59		87	
Adjusted R^2 (OLS)	-0.39		-0.39	
Log-likelihood	-502.2		-736.9	
Test for heteroskedasticity[2]				
LM statistics	78.45		88.96	

Variable or Model Summary Characteristic	Number of Hired Labourers		Payments to Hired Labour, KSh/month	
	Marginal effect	t-stat	Marginal effect	t-stat
Probability	0.00		0.00	
Test of Specification for Prob[Y*<0][3]				
LR statistic	85.32		91.57	
Probability	0.00		0.00	

[1] The formulation of Cragg (1971) involves sequential estimation of probit and truncated regression models, which allows for the direction of impact of X on Prob[Y*<0] to differ from the direction of impact of X on E[Y|Y*>0|X]. Reported results are for the truncated regression. Although tests indicate presence heteroskedastic errors, heteroskedastic truncated models would not converge.

[2] Conditional moment test using LM statistic (Pagan and Vella, 1989).

[3] Likelihood test using log-L values from Tobit, probit and truncated regression models (Greene, 2000).

OTHER A.E.M. WORKING PAPERS

WP No	Title	Fee (if applicable)	Author(s)
2002-07	The Political Economy of Long-Run Growth in Angola - Everyone Wants Oil and Diamonds but They Can Make Life Difficult		Kyle, S.
2002-06	Exploitation of Child Labor and the Dynamics of Debt Bondage		Basu, A. K. and N. H. Chau
2002-05	A Note on Public Goods Dependency		Kanbur, R. and D. Pottebaum
2002-04	Dutch Disease in São Tomé E Príncipe: Policy Options for the Coming Oil Boom		Kyle, S.
2002-03	Portugal and the Curse of Riches - Macro Distortions and Underdevelopment in Colonial Times		Kyle, S.
2002-02	University-Wide Entrepreneurship Education Alternatives Models and Current Trends		Streeter, D., J.P. Jaquette, Jr. and K. Hovis
2002-01	The New Partnership for Africa's Development (NEPAD): An Initial Commentary		Kanbur, R.
2001-24	Class, Community, Inequality		Dasgupta, I. and R. Kanbur
2001-23	Civil War, Public Goods and the Social Wealth of Nations		Pottebaum, D. and R. Kanbur
2001-22	A Review of the New Undiscovered Conventional Crude Oil Resource Estimates and Their Economic and Environmental Implications		Chapman, D.
2001-21	Payment Certainty in Discrete Choice Contingent Valuation Responses: Results from a Field Validity Test		R. Ethier, G. L. Poe, C. A. Vossler, and M. P. Welsh
2001-20	The Determinants of Girls' Educational Enrollment in Ghana		Johnson, R. and S. Kyle
2001-19	Economics, Social Science and Development		Kanbur, Ravi
2001-18	Does Specification Error Explain the Discrepancy Between Open-Ended and Dichotomous Choice Contingent Valuation Responses? A Comment on "Monte Carlo Benchmarks for Discrete Valuation Methods" by Ju-Chin Huang and V. Kerry Smith		Poe, G. L. and C. A. Vossler
2001-17	Measuring the Effects of Eliminating State Trading Enterprises on the World Wheat Sector		Maeda, K., N. Suzuki, and H. M. Kaiser
2001-16	Disentangling the Consequences of Direct Payment Schemes in Agriculture on Fixed Costs, Exit Decision and Output		Chau, N. H. and H. deGorter

Paper copies are being replaced by electronic Portable Document Files (PDFs). To request PDFs of AEM publications, write to (be sure to include your e-mail address): Publications, Department of Applied Economics and Management, Warren Hall, Cornell University, Ithaca, NY 14853-7801. If a fee is indicated, please include a check or money order made payable to Cornell University for the amount of your purchase. Visit our Web site (*http://aem.cornell.edu/research/workpaper3.html*) for a more complete list of recent bulletins.