Household-level Impacts of Dairy Cow Ownership in Coastal Kenya

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This study uses heteroskedastic Tobit and Censored Least Absolute Deviations 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 gross household cash income, gross non-agricultural 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 at least 53% of the mean total income of households without dairy cows. Dairy cow ownership also increases consumption of dairy products by 1.0 litre per week, even though most of the increase in milk production is sold. The number of dairy cows has no significant effect on total labour for cattle-related tasks. However, in contrast to previous studies, labour allocation to cattle by household members decreases and labour requirements for dairy cows are met primarily by an increase in hired labour. Dairy cow ownership results in relatively modest increases in payments to hired labourers and the number of hired labourers employed. The large positive impacts on income and the substitution of hired for household labour in cattle care suggest that intensification of smallholder dairying can be beneficial as a development strategy in the region if disease and feed constraints are addressed.

1. Introduction

In many parts of Sub-Saharan Africa, smallholder 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 smallholder farmers who continue to dominate African production (Staal *et al*., 1997). Market-oriented dairy production may fill this need for some smallholder producers, particularly in light of expected rapid growth in milk consumption in the developing world over the next two decades (Delgado *et al*., 1999).

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Intensification of smallholder 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 smallholder 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 can thus result in increased incomes for smallholders. Cash receipts from milk and dairy product sales typically are distributed more evenly throughout the course of a year than income from crop sales. Because dairy production tends to be labour intensive, it can increase the intensity of household labour use and generate hired employment. This may stimulate the demand for labour, providing benefits to unskilled labourers and distributing the gains from dairy production more broadly and progressively. Cattle with European germplasm[2], 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 can also 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 smallholders 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.

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[2] 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”) 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 smallholders in coastal Kenya is much less frequent. The coast of Kenya is of interest because limited dairy co-operative 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 more than one-third of children suffer from moderate to severe chronic malnutrition (Foeken *et al.*, 1989; Nicholson *et al.*, 2002). 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 gross household cash 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-agricultural income in coastal Kenya, we also explore whether dairy cow ownership complements or substitutes for gross non-agricultural 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 *Pennisetum purpureum*, 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,” 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.

2. The Study Area

Coast province covers over 80,000 square kilometres in the South-eastern 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. 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-agricultural activities. 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-agricultural activities results from the low-to-moderate potential of the region for intensification of agriculture, and the need to diversify household activities to reduce risk. 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 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 smallholder 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 smallholder farms. Local Zebu breeds produce the majority of milk. 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 smallholders, 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).

3. 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. 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:

$$Y = Y(\mathbf{Z}^h, \mathbf{Z}^c, P^m, P^a, P^b, w^a, w^b, A, K^a, K^b, E, DC, LC) \qquad (1)$$

where:

Y = Endogenous impact variable (*e.g.*, Income)
$\mathbf{Z}$ = Exogenous characteristics *(h* = Household; *c* = Community*)*
P = Price of good *(m* = purchased*; a* = agricultural; *b* = non-agricultural*)*
w = Wage rate *(a* = agricultural; *b* = non-agricultural*)*
E = Exogenous income *(e.g.,* remittances*)*
K = Other capital assets *(a* = agricultural*; b* = non-agricultural*)*
DC = Number of dairy cows owned by the household
LC = Number of local cattle owned by the household
A = Total land area owned or occupied by the household

All the endogenous variables of interest 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 out 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. The equations for time spent in cattle related tasks by household members and hired labour are estimated using data only for those households owning cattle, given that under normal circumstances households must own cattle for non-zero labour allocations to be observed.

Because of the nature of dairy cows as a capital good and the fact that the diffusion process of the technology (Rogers, 1995) was essentially complete by the period of data collection, the number of dairy cows may be predetermined for the purposes of other household decisions. However, the assumption of exogeneity of dairy cows owned is tested for each dependent variable based on the hypothesized model:

$$\begin{aligned} Y &= \boldsymbol{\beta}_1' \boldsymbol{x}_1 + \gamma \cdot DC + \varepsilon_1 \\ DC &= \boldsymbol{\beta}_2' \boldsymbol{x}_2 + \varepsilon_2 \end{aligned} \qquad (2)$$

where the $\boldsymbol{x}$'s represent vectors of exogenous variables[3] in the reduced-form equation (1). A t-test of the hypothesis that $\psi = \sigma_{12} / \sigma_2{}^2 = 0$ is a test for the exogeneity of DC (Greene, 2000). For each of the dependent variables of interest, the hypothesis of exogeneity of DC could not be rejected. Thus, the number of cows is treated as predetermined in each of the estimated equations.

Because heteroskedasticity is typically a problem in household survey data, and implies inconsistent parameter estimates in the censored regression model (Deaton, 1997), two alternative estimation approaches are employed. First, all model formulations are tested for heteroskedastic error terms using the conditional moment LM test proposed by Pagan and Vella (1989). When the LM test rejects the hypothesis of homoskedastic error terms, maximum likelihood estimation is undertaken assuming multiplicative heteroskedasticity of the form $\sigma_i^2 = \sigma^2 \exp\{\gamma' z_i\}$, where z is the set of variables that includes land area, number of dairy cows, age and education of household head. Second, all models are also estimated using the Censored Least Absolute Deviations (CLAD) estimator (Powell, 1984). Based on the approach used by Buchinsky (1994), this estimator involves the iterative application of the Least Absolute Deviations (LAD) estimator. This estimator does not require knowledge of the distribution of the error terms or homoskedasticity to be consistent. The first estimation includes all observations, whereas subsequent estimations are based on only those observations for which the predicted values of $Y = \boldsymbol{x}'\boldsymbol{\beta}$ are non-negative. Standard errors for the parameter estimates are bootstrapped using 1000 random samples drawn with replacement. All models are estimated using LIMDEP software (Greene, 1998).

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[3] Exogenous variables in the equation for DC (*i.e.*, x_2) include distance to closest market, district location, land area owned, land tenure status, number of cattle housing structures, gift and remittance income, household head characteristics (age, sex, education) participation in a livestock development project, household ethnic group, household stage of development, milk price, and number of local cows owned. Land area, cattle housing and local cows have statistically significant positive impacts on dairy cow numbers owned.

4. Data

Data to estimate the models described above are 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. For this survey, the sample of households was stratified by dairy cattle ownership and division (the administrative unit below the district level) because the divisions south and north of Mombasa differ substantially in infrastructure development and the degree of trypanosomosis challenge. MALDM extension agents administered a structured questionnaire in multiple visits to each household during February to April 1998. Of the 198 households surveyed, 184 were classified as smallholder households. The others were expatriates or absentee owners whose principal source of income was a non-agricultural 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 smallholder 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 Appendix Table 1.

The specific variables include household locational characteristics such as distance to markets and milk purchase point. These distances were estimated by the households surveyed, and represent a measure of transport and some transactions costs in dairy production and marketing. 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, the tenure status of landholdings and the number of cattle-housing 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 smallholder 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.

Household demographic factors will also affect observed outcomes of the endogenous variables of interest. 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 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) 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. The number of household members, age of the household head and the dependency ratio define these stages.

Price and wage variables include the milk price and an estimated maximum wage rate for the household. The milk price is that 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 during the last four months, the price at which the household believed milk could be sold as of the survey date. The maximum wage rate for each household captures the potential earnings of the household in non-agricultural labour. To construct this variable, the daily compensation for all household members reporting non-agricultural 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-agricultural 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 gross household cash income, gross non-agricultural cash income, dairy product consumption, labour spent in cattle-related tasks by household members and hired labour, total payments by the household to hired labour and the number of labourers employed at the time of the survey. Information on gross household cash income was based on activity-specific recall information of crop production and sales, dairy and livestock product sales, income from land rental or sharing, and gift or remittance income during the prior year. Information on gross cash income from wage labour, salaries and business activities was based on activity-specific recall information for the previous four months. Income from all sources was summed and converted to a monthly equivalent in Kenya Shillings (KSh). Non-agricultural cash income included wages, salaries, and business income, and 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.

5. Results

5.1 Impacts on Gross Household Cash Income and Non-agricultural Cash Income

One of the main hypothesized impacts of dairy cow ownership is increased household income, primarily from increased milk sales. Households owning dairy cows report significantly higher gross cash income per month (Appendix Table 1), 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-agricultural cash income is comparable among households with no cattle, only local cattle, and dairy cows.

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 smallholder 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 smallholder households. The cash cost of the cow, although substantial (about 40,000 KSh, or 83% of the average annual gross cash income per household), is not included in current gross cash income because most households reported purchasing dairy cows with cash saved previously either individually or through communal savings programs (*harambee*). To the extent that this approach ignores inter-temporal savings effects, it will tend to overstate the current income benefits of dairy cow ownership. Hired labour is employed by 50% of households with dairy cows, so some allocation of hired labour costs to dairy cow ownership is appropriate. Payments to hired labour per dairy cow owned are assessed subsequently, and are estimated to account for about 5-10% of the revenues from milk sales. Although our estimates of the impacts on gross cash income overstate the effect of dairy cow ownership, the impact on net cash household income is still likely to be positive and of a large enough magnitude to be relevant for development policy purposes.

The models of gross household cash income indicate that dairy cow ownership has a statistically significant positive impact. The marginal effect of each cow is 2,115

KSh per month in the heteroskedastic Tobit (HT) model and 3,488 KSh per month in the CLAD model[4] (Table 1).

Table 1: Marginal Effects of Dairy Cow Numbers on Outcome Variables

Outcome Variable	Heteroskedastic Tobit			Censored Least Absolute Deviations		
	Marginal	s.e.	t-stat	Marginal	boot s.e.	t-stat
Household cash income	2,115.0	442.3	4.8	3,488.2	817.3	4.3
Non-agricultural income	14.6	135.8	0.1	-339.6	555.7	-0.6
Milk consumption	1.4	0.5	2.8	1.0	0.6	1.8
Total cattle labour	165.5	220.5	0.8	169.4	242.9	0.7
Household cattle labour	-197.0	77.9	-2.5	-196.6	284.0	-0.7
Hired cattle labour	331.2	92.3	3.6	983.8	523.9	1.9
Hired labour payments	288.3	61.3	4.7	253.9	330.9	0.8
Number of hired labourers	0.08	0.03	3.0	0.05	0.2	0.2

Note: This table summarises parameter estimates only for the number of cows owned. Full model estimation results are available from the authors upon request.

These amounts are equivalent to 53 to 87% of the monthly gross cash income from all sources for sample households without dairy cattle (Appendix Table 1). 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. The parameter estimates for other variables are generally qualitatively similar for the two estimation procedures. As expected, the standard errors are often larger for the CLAD model formulation so that the number of statistically significant variables differs. In the HT model, other variables with a statistically significant positive marginal effect on household cash income include location in the number of wheeled carts and vehicles, the number of adults in the household, and the estimated maximum wage. Households located in Malindi district have significantly lower cash income than households in the other districts in both models. The magnitude of the increase in cash income due to cow ownership is less than the effect of owning a vehicle and somewhat comparable to that of owning a wheeled cart.

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

Ownership of dairy cows may substitute for alternative non-agricultural economic activities chosen by household, as indicated by the negative marginal effect of dairy cow numbers on non-agricultural income (Table 1). In the HT model formulation, the principal effect is on the scale parameter, *i.e.*, on the heteroskedastic term and not on the coefficient. The magnitude of the combined estimated effect is relatively small, just over 4% of the mean total household income for households owning dairy cows. Nevertheless, this is consistent with observations by Waaijenberg (1994) about the basic substitutability between agricultural and non-agricultural activities at the Kenya coast. In the CLAD model formulation, the estimated effect is smaller and not statistically significant. Increases in non-agricultural income are positively associated with the number of wheeled carts, vehicles owned and maximum estimated wage in the HT model, and by the number of adult household members in both models. The negative marginal effect of household head age in both models may be explained by a transition process in which younger households choose to focus more on non-agricultural activities. Households in Malindi district again had significantly lower non-agricultural incomes in both model formulations.

5.2 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 report consuming milk or dairy products during the previous week. A larger proportion of the households with dairy cows (75%) consumed milk. Moreover, adopting households consume more milk on average—in total or per consumer unit—than households with no cattle or only local cattle (Appendix Table 1). Ownership of dairy cows has a statistically significant marginal effect on total dairy consumption, increasing consumption of milk equivalent by 1.0 to 1.4 litres per week for each dairy cow owned (Table 1). This increase is one-third to one-half of the mean household consumption of dairy products for households without dairy cows. Analogous to the distinction above between impacts on gross income versus net income, our estimates to do not account for substitution effects among food consumed by the household as a result of dairy cow ownership[5], and thus may overstate the increase in nutrient consumption by the household. Even if substitution effects are limited, the net increase in consumption is small relative to total caloric and protein intake. However, the micronutrient (*e.g.*, Vitamin A) content of this amount of milk may have positive health benefits, particularly when the milk is fed to post-weaning children (Neumann, 1998).

Participation in a livestock development project and being a member of a migrant ethnic group had statistically significant positive impacts on milk consumption in both models. The number of local cows owned had a smaller but positive effect in the HT model, and the number of adults had a statistically significant positive effect in the CLAD model. Theory predicts a negative relationship between milk price and dairy consumption, and the marginal effect in the model is negative but statistically

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[5] Data on household food consumption was limited to dairy products.

insignificant in both model formulations. 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, other household 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 micro-nutrient bio-availability 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).

5.3 Impacts on Labour Allocation to 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 data from 105 households owning cattle, although a small number of households without cattle report allocating labour to cattle care. Despite a larger amount of time allocated to cattle tasks by households with dairy cattle compared to those with only local cattle

[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.

(Appendix Table 1), there are no statistically significant impacts of dairy cow numbers on total labour for cattle tasks in either model (Table 1). Other factors, such as location (in Malindi district), participation in a development project, the number of adults in the household, and the household's stage of development, appear to be more important than cattle numbers *per se*. On average, households with dairy cows allocate greater total labour to cattle tasks, but this allocation may not be strongly related to the number of cows owned due to the nature of the tasks related to cattle. Although the NDDP promoted full confinement cattle housing (termed "zero-grazing"), this practice was often ill-adapted to production conditions in coastal Kenya. A large proportion of the labour for cattle is for herding cattle grazing natural stands of grass along roadsides, even for dairy cows. Children often perform this activity, and it is relatively little affected by small increases in the number of animals.

There may be a negative effect of dairy cow ownership on labour by household members allocated to cattle tasks. For this dependent variable, the heteroskedastic Tobit model does not converge. Results are reported for the standard Tobit, which is likely to be biased upward (Deaton, 1997), and the CLAD model. The standard Tobit model indicates a statistically significant negative effect of dairy cows and the CLAD a negative effect of quite similar magnitude that is statistically insignificant (Table 1). Land area owned or occupied has a positive marginal effect on household labour allocated to cattle-related tasks in the HT model; being in the "establishment" stage of household development had a negative impact. No variables are statistically significant in the CLAD model. The combination of an increase in cattle-related labour requirements and no impact on labour by household members suggests that labourers hired from outside the household provide much of the additional labour for dairy cows. 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.

5.4 Impacts on Hired Labour

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: 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 (Appendix Table 1). Total payments to hired labourers are also substantially different for households with and without dairy cows. 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 ploughing and weeding. The additional time required for one dairy cow typically does not

[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 the number of dairy cows owned.

fully occupy one hired labourer. Moreover, the range of observed values for the number of hired labourers is small: 90% of smallholder 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. For this dependent variable, the LM test does not reject the hypothesis of homoskedastic errors, so the standard Tobit results are reported. Each dairy cow increases the time spent by hired labour between 5 and 16 hours per week for the Tobit and CLAD models, respectively (Table 1). This suggests a dairy cow ownership results in the substitution of hired labour for household labour to meet the overall increase in labour demands. The level of education for the household head and being in the expansion stage of development is associated with a statistically significant increase in hired labour allocated to cattle tasks in the Tobit and CLAD models. Location in Malindi district and participation in a livestock development project have significant positive impacts in the Tobit model, whereas the land area owned or occupied and the number of adults in the household have a statistically significant negative effect on the amount of hired labour allocated to cattle tasks in the Tobit model.

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.

In the HT model, the number of dairy cow owned has a statistically significant effect on payments per month to hired labour of 288 KSh, or about four day's wages at the mean wage rate for hired agricultural labourers in the sample (Table 1). A similar effect is noted for the CLAD model, 255 KSh, but this effect is not statistically significant. Similar to the models for hired labour allocation, education of the household head has a statistically significant positive effect on labour payments in the HT model, as does being in the expansion stage of household development. Location in Kilifi district has a statistically significant negative effect in both models. Male-headed households, the number of adults and being in the consolidation stage of household development, all have statistically significant negative effects in the HT model.

The number of hired labourers is examined with standard Tobit formulation because the LM test does not reject the hypothesis of homoskedastic error terms. In the Tobit model, the number of dairy cows owned has a statistically significant positive effect—albeit a small one—on the number of hired labourers (Table 1). The coefficient of 0.08 suggests that roughly 13 additional dairy cows are needed to generate one additional hired labourer. In the CLAD model, a somewhat smaller effect is noted, 0.05 additional hired labourers per dairy cow, and this effect is not statistically significant. In the Tobit model, participation in a livestock project has a large statistically significant positive effect of 0.49 hired labourers, as does being in the expansion stage of household development. Higher levels of household head education have a positive impact on the number of hired labourers, and location in Kilifi district, male-headed households and the consolidation stage of household development have negative effects on hired labourers in the Tobit model. The positive but small impact on the number of hired labourers given the increase in hired labour allocated to cattle-related tasks suggests a re-allocation effect. Households that hire labour allocate that labour differently if they own dairy cows than if they do not, without substantially increasing the overall amount of labour hired. Households with dairy cattle allocate a substantial portion of the labourers' time to cattle-related tasks, whereas households without will allocate that time to other (non-cattle) activities. In sum, hired labourers appear to 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 increases in labour payments or employment.

6 Discussion

The results of our study in coastal Kenya suggest that ownership of dairy cows can result in positive outcomes for smallholder 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, and there may be positive effects on secondary employment generation. Taken as a whole, these results suggest that more intensive dairying has a number of benefits and few drawbacks from the individual households' perspective. Thus, empirical evidence suggests there are benefits from efforts to promote ownership of dairy cows and improve management practices by smallholder 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-agricultural 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 key assets do, in fact, own dairy cows (Table 2). 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 appear to preclude dairy cow ownership. Lack of monetary capital and other productive assets undoubtedly prevent many smallholders 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 smallholder dairy production at the coast is complex. Households have various non-agricultural options for generating income that may serve the same purposes, and dairying therefore represents only one of many alternatives. Our results suggest possible substitutability between dairy ownership and non-agricultural income sources. As a result, 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.

Table 2: Dairy Cow Ownership by Resource and Non-agricultural Income Quartile

Asset or Income Category	Bottom Quartile		Top Quartile	
	Upper Limit	% with dairy cows	Lower limit	% with dairy cows
Land area, ha	4.0	17.4	12.0	52.2
Plows owned	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-agricultural income, KSh/month	0.0	41.3	3,270.0	37.0

Note: N=184 smallholder households, 46 households per quartile, except for plows owned, with N=45 households in bottom quartile.

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 smallholders to achieve the full potential for positive impact. Two key areas in need of further evaluation are the level of 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 smallholders 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 smallholder 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 smallholders with specific characteristics. Developments in these areas would increase the propensity of smallholders 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.

7 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 have offered smallholder dairy producers, current or potential, large margins for their milk. However, these markets and their environs also offer other opportunities for the investment of smallholders' scarce capital. Many of these investment opportunities require less investment than dairy cattle, fewer specialist skills and less total labour. Nevertheless, as smallholder 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.

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APPENDIX TABLE 1: HOUSEHOLD CHARACTERISTICS AND VARIABLES, BY CATTLE OWNERSHIP STATUS

Variable	Cattle Ownership Status			
	Without Dairy Cattle			
	No Cattle (N=77)	Local Cattle (N=44)	Total (N=121)	Dairy Cattle (N=63)
Exogenous Variables				
Household Location Characteristics				
Distance to market, km	3.50	2.96	3.30	3.97
	(3.83)	(2.06)	(3.28)	(5.15)
Distance to milk purchase, km	1.94	2.78	2.25	3.29
	(2.54)	(2.23)	(2.45)	(4.78)
District dummy (1=Kilifi)	0.43	0.11	0.31	0.44
District dummy (1=Malindi)	0.04	0.50	0.21	0.30
Agricultural Capital				
Land area owned /occupied, acres	8.14	11.05	9.20	18.27
	(12.41)	(6.87)	(10.79)	(25.72)
Tenure (1=Title deed; 0=Informal)	0.58	0.84	0.68	0.86
Number of cattle housing structures	0.01	0.14	0.06	0.59
	(0.11)	(0.35)	(0.23)	(0.50)
General Capital and Resources				
Number of wheeled carts	0.01	0.09	0.04	0.17
	(0.11)	(0.29)	(0.20)	(0.38)
Number of vehicles	0.03	0.00	0.02	0.08
	(0.16)	0.00	(0.13)	(0.33)
Number of 'permanent' houses	0.12	0.34	0.20	0.59
	(0.40)	(0.81)	(0.59)	(1.03)
Gift/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)	0.94	0.89	0.92	0.95
Education of household head, years	4.86	4.16	4.60	7.30
	(4.50)	(4.03)	(4.33)	(4.74)
Participation in livestock project (1=Yes)	0.21	0.12	0.18	0.51
Household Demographic Characteristics				
Migrant to Coast? (1=Yes)	0.14	0.25	0.18	0.21
Number > 14 years old in household	4.90	6.55	5.50	6.24
	(2.57)	(3.55)	(3.06)	(3.39)

Variable	Cattle Ownership Status			
	Without Dairy Cattle			
	No Cattle (N=77)	Local Cattle (N=44)	Total (N=121)	Dairy Cattle (N=63)
Household stage of development (1=Establishment)	0.19	0.05	0.14	0.03
Household stage of development (1=Expansion)	0.35	0.48	0.40	0.54
Household stage of development (1=Consolidation)	0.34	0.34	0.34	0.25
Prices and Wage				
Milk price, KSh/litre	31.30	31.03	31.20	26.50
	(11.14)	(7.43)	(9.92)	(7.57)
Maximum estimated wage, KSh/day	177.90	161.34	171.88	242.84
	(190.08)	(169.64)	(182.37)	(595.85)
Cow Ownership				
Number of local cows owned	0.00	1.77	0.64	1.21
	--	(1.87)	(1.41)	(3.18)
Number of dairy cows owned	0.00	0.00	0.00	2.43
	--	--	--	(5.24)
Endogenous Variables				
Household cash income, KSh/month	3,841.15	4,298.52	4,007.47	12,763.77
	(4,995.81)	(5,095.40)	(5,015.88)	(25,155)
Non-agricultural cash Income, KSh/month	2,905.72	2,343.98	2,701.45	3,203.60
	(4,005.53)	(4,800.19)	(4,300.19)	(5,993.2)
Milk consumption, milk equivalent litres/week	2.11	4.41	2.93	9.03
	(2.34)	(5.32)	(3.84)	(10.57)
Total cattle labour, minutes/week	3.12	3,227.82	1,175.74	4,781.35
	(19.21)	(2,273.23)	(2,068.41)	(3,131.4)
Household cattle labour, minutes/week	1.56	2,471.34	899.66	2,059.40
	(13.68)	(2,432.59)	(1,882.51)	(1,956.5)
Hired cattle labour, minutes/week	1.56	756.48	276.07	2,721.95
	(13.68)	(1,439.88)	(935.95)	(3,242.6)
Total payments to hired labourers, KSh/month	182.79	164.39	176.10	1,163.10
	(469.85)	(411.31)	(447.79)	(1,696.7)
Number of hired labourers	0.64	0.36	0.54	1.52
	(1.10)	(0.69)	(0.98)	(1.61)