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DAIRY COW OWNERSHIP AND CHILD NUTRITIONAL STATUS IN KENYA

By

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PREFACE

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Dairy Cow Ownership and Child Nutritional Status in Kenya

ABSTRACT

Dairy cow ownership has been widely promoted by a number of development projects in Kenya (and other countries in East Africa) for the last two decades, and the country has the largest population of smallholder producers with dairy cows in sub-Saharan Africa. Supporters of dairy development efforts often have assumed that there will be positive nutritional impacts from increased milk consumption by dairy cow-owning households. This expectation has been further strengthened by recent research findings about the micronutrient benefits of animal product consumption. However, the nutritional impacts of more intensive dairying have received relatively little study to date in East Africa.

This paper develops a conceptual framework that identifies key pathways through which dairy cow ownership may have both positive and negative impacts on child nutritional status. Using household- and child-level data on dairy cow owners and non-owners in coastal and highland Kenya, two alternative econometric models are used to estimate the impacts of the number of dairy cows owned, controlling for child characteristics, household head characteristics, and other household characteristics. To explore a principal hypothesized pathway through which dairy cows may influence nutritional outcomes, additional econometric models explore the impact of household income on nutritional status.

Consistent with two previous studies, cattle ownership *per se* had a statistically significant positive impact on height-for-age (a measure of longer-term growth) in both regions. The number of dairy cows has a limited impact on weight-for-height, a measure of short-term child nutritional status. In coastal Kenya, however, there is evidence that dairy cow ownership has a positive impact on height-for-age. Household income has limited positive impacts on nutritional status at the coast. In the Kenyan highlands, our results suggest a marginally significant negative impact of household income on both weight-for-height, but existing data do not allow exploration of the sources of this anomalous result.

Overall, the evidence suggests that dairy cow ownership *per se* does not result in negative nutritional impacts of dairy cow ownership, which implies that dairy development efforts have not increased child malnutrition. However, the evidence also suggests that positive nutritional

impacts expected for more intensive dairying—particularly from increases in household income—may be limited. Further site-specific study of the pathways influencing household nutrient allocation, child morbidity, and labor requirements should be undertaken to inform policy and program efforts to enhance the nutritional benefits of dairy cow ownership.

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INTRODUCTION

Malnutrition continues to affect large numbers of children in the low-income countries of the world, despite reductions in the proportion of malnourished children in some regions during the last 30 years. In sub-Saharan Africa, an estimated one-third of children—more than 30 million—were underweight in 1995. In contrast to overall global trends, the number of malnourished children in sub-Saharan Africa has increased in recent decades. Moreover, a recent study indicated that between 43 and 55 million children in the region will be underweight in 2020—an increase of 38 to 77% (Smith and Haddad, 1999). In Kenya, child malnutrition continues to be a serious problem. Nearly one-third of children showed evidence of chronic malnutrition in the mid 1990s, and more than six percent were acutely malnourished (Mwangi, 2001). It is well-known that the causes of child malnutrition are complex and multidimensional, and that the aggregate impacts on individuals and the development process are large and long-lasting. Despite agreement on the scope and importance of the problem, there is no clear consensus of the most important causes of child malnutrition, and on which policies or programs would most effectively address it.

Latham (1997) noted that the underlying causes of child malnutrition (poverty, lack of knowledge, disease, inadequate food supplies) have not changed in the past 50 years, but that the interventions to address the problem tend to vary decade by decade. The 1990s saw progress in reducing the number of underweight children in some regions, but also a growing awareness of the importance of micronutrients (vitamins and minerals) in child growth (Underwood, 1998). The focus on micronutrients led to increasing interest in understanding the potential role of animal products to address micronutrient deficiencies, particularly for iron, zinc, iodine, vitamin A and vitamin B_{12} (Neumann, 1998), because "animal source foods have a positive impact on quality and micronutrient enhancement of the diet of women and children, and can prevent or ameliorate many micronutrient deficiencies" (Neumann et al., 2002). Diets in many parts of Kenya are maize-based, bulky, and can be low in energy density. They are also high in fiber and phytate content, which reduces bioavailability of micronutrients (Neumann et al., 2002).

As a result, a number of studies have examined the impact of animal product consumption on child growth performance (see summary of selected studies in Appendix Table 1). The studies suggest that under certain circumstances moderate animal product consumption, especially meat, can improve child growth and cognitive development, due to greater energy density of the diet, and improved biological availability of the forms of micronutrients found in animal products (e.g., Allen et al., 1992; Marquis et al., 1997; Neumann et al., 2002). Although further study is merited (in part to address methodological limitations of previous studies) and the effect is not statistically significant for all groups of children in all studies, increased consumption of "animal source foods" appears to have the potential to result in improvements in child nutritional status (Nnanyelugo, 1984; Latham, 1997). To the extent that animal products improve diet quality and child growth, a key challenge is how to increase their consumption (especially by children), given that this depends critically on household decisions—which are in turn based on incomes and preferences (Senauer, 1990; von Braun et al., 1994).

Concurrently, efforts continue to identify opportunities to increase food production and income generation, because both production and income are associated with improvements in household nutritional status (Low, 1991; von Braun et al., 1994). In selected regions of the sub-Saharan Africa, one option for increasing food production and household incomes is dairy production and marketing. In much of East Africa, dairying by smallholder farm families is viewed by governments and development agencies as a means of increasing the production of needed nutrients, and as a source of cash income to purchase other foods (Staal *et al.*, 1997). The potential contribution of dairying to household welfare has led to efforts to develop new technologies and production practices that can be used by resource-poor households in the region. 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, although use of complementary feeding and health inputs is common. Promotion of these technologies is often the focus of what has been termed 'dairy development'[2]. Because dairy cows[3] can increase

[1] This includes a number of cattle breeds, including Holstein, Jersey, and Brown Swiss, which originated in Europe.
[2] In contrast, the well-known dairy development efforts in India focused on development of transportation and marketing organizations and infrastructure through producer dairy cooperatives. Dairy development in Kenya built upon a well-developed number of dairy cooperatives, but the NDDP focused on increasing production.
[3] 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.

milk production and household incomes by substantial amounts, they have been widely adopted in the cooler highlands of East Africa (particularly in Kenya and Tanzania).

In Kenya, the National Dairy Development Project (NDDP) actively promoted dairy cow ownership and use of related technologies in 24 districts over the course of 15 years. Despite the considerable resources devoted to dairy development, relatively little is known about the nutritional impacts of dairy cattle ownership (see summary of studies in Appendix Table 2). Four studies from East Africa have indicated a positive relationship between child nutritional status and dairy cow ownership. Hitchings (1982) found that child height was positively related to ownership of a milk cow if the milk tended to be used for the family's own consumption. In coastal Kenya, Leegwater et al. (1991) noted that the nutritional status of pre-school children in households participating in the NDDP (or their customers) had better nutritional status than children from the general population. Ownership of a cow in rural Uganda was found to be a strong predictor of child height-for-age, controlling for land area owned and education of the household head (Vella et al., 1995). In rural Rwanda, an index of dairy animal ownership had a strong positive impact on child height-for-age, controlling for maternal characteristics, household income, and environmental factors (Grosse, 1998b). Moreover, studies examining the role of non-dairy livestock (beef cattle, chickens, pigs, etc.) tend to indicate that ownership of these animals has no strong relationship with child nutritional status (Annan, 1985; Vella et al., 1995; Grosse, 1998a).

Despite the results from these studies, a number of limitations exist in the scope of the analyses and the methods used. First, the analyses often do not distinguish impacts by the type of cow owned. In many areas, both local and dairy cows are present, but typically the latter have been the focus of dairy development efforts. Second, the pathways by which dairy cow ownership results in nutritional benefits have not been formally examined in any of the studies. Thus, it is uncertain whether the impacts of dairy cow ownership arise primarily through consumption of milk from own production, or from higher incomes resulting from increased milk sales. Information about the pathways of impact would allow development of complementary policies or programs to enhance the nutritional impact of dairy development. Finally, methods employed were sometimes inconsistent with the analytical framework deemed appropriate by economists, which recognizes the importance of household decisions to determine food production, allocation of food, and child nutritional status. Thus, the reported impacts may be biased due to the statistical methods used.

The paper has three principal objectives. The first is to describe a conceptual framework to enhance understanding of the potential impacts of dairy cow ownership on household welfare, with an emphasis on child nutritional status. This framework will help to place the subsequent statistical analyses into context, and demonstrate the complexity of the pathways influencing child nutrition. The second is to examine the impact of cattle ownership generally, and dairy cow ownership more specifically, on the nutritional status of pre-school children in two regions of Kenya using household-level data and econometric estimation techniques. These estimates will address the question of whether dairy cow ownership has positive, negative, or limited impact on child nutritional status. A third objective is to explore the effects of household income, one of the pathways through which dairy cow ownership may influence child nutritional status, again using econometric estimation. This information will offer insights into how to enhance the nutritional impacts of dairy development efforts in the region. The emphasis herein is on indicators of malnutrition more commonly associated with macronutrient deficiencies (such as energy and protein), rather than on micronutrients (although in some cases there are interactions between the two). This is appropriate given that protein-energy malnutrition (PEM) remains "the most important nutritional problem in…Africa" (Latham, 1997).

CONCEPTUAL FRAMEWORK

Numerous conceptual frameworks have been developed to examine the causes and consequences of child malnutrition (e.g., UNICEF, 1990; von Braun et al., 1994; Grosse, 1998b). The conceptual framework developed herein emphasizes the main pathways by which dairy cow ownership may influence child nutritional status, and therefore omits or diminishes the importance of some factors described in previous frameworks. However, our framework explicitly acknowledges the presence of important feedback loops and key system state variables (also referred to as stocks) that have important implications for the dynamics of household welfare, including child nutrition (Sterman, 2000).

Child nutritional status is intertwined with child health status. This is depicted as two state variables, each that positively influences the other[4] (Figure 1). Child nutritional status is determined by the intake of nutrients by the child, as well as the current health status, because the presence of infection can influence intake, absorption, use and requirements of nutrients by the child (Latham, 1997). Nutritional status influences health because malnourished children often have weaker immune response and reduced resistance to disease due to decreased integrity of skin and mucous membranes. The three conditions necessary to support child growth include adequate household nutrient availability (from own production or purchases), appropriate child care and feeding practices (Engle et al., 1999), and health care sufficient to maintain child health status. The first two of these three primarily influence child nutrient intake, whereas that last influences both intake and utilization of nutrients. Nutrient availability for the other members of the household can have indirect impacts on child nutritional status, because the nutritional status of adults can influence food crop production and wage labor (and therefore household cash income) and the amount and quality of care and feeding behavior.

The impacts of dairy cow ownership on child nutritional status can result from a number of different pathways. One pathway involves the competition between resources allocated to dairy cows versus food crops. Ownership of dairy cows (or an increase in their number) is expected to result in a decrease in the resources (especially the land area) devoted to food crops[5], which, other things being equal, would reduce household nutrient availability. However, dairy cows may also contribute to more rapid and efficient nutrient cycling, which could increase soil nutrient content and crop yields (Delve et al., 2001). Moreover, dairy cows increase milk production, which can result in an increase in both nutrient availability (if the milk is consumed) and household cash income (if the milk is sold).

The impact of an increase in household income from dairy production may be a crucial link in understanding the impacts of dairy cow ownership on child nutrition. If additional income is spent on food, this increases household nutrient availability, assuming that the household does not simply use higher incomes to purchase more expensive calories, protein, or micronutrients

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[4] Some authors have argued that the more general term "health status" should be used rather than separating health and nutritional status. However, the distinction between the two can be helpful to represent how infection interacts with malnutrition. Note that the formulation in the figure for the relationship between child nutritional status and health status is general and allows non-linear and non-additive (synergistic) effects.

[5] The NDDP actively promoted a cut-and-carry forage system using improved grass species, which in the absence of specialized forage producers or underutilized land would imply competition with land devoted to other crops.

(Senauer, 1990; Kennedy, 1994). Additional income spent on health-related inputs can complement the impacts of increased food expenditures. The propensity of the household to spend additional income on food and health-related items is often associated with gender patterns of income control (Thomas, 1997; Tangka et al., 2000). If cow ownership reduces household income controlled by women (who tend to have higher propensities to spend additional income on food and health), then the nutritional impacts of cow ownership could be muted or negative. However, if additional income is invested in other productive assets, this may increase non-agricultural income and household income over time, suggesting positive impacts if some of that additional income is used to increase household nutrient availability.

Another potential pathway for negative impacts is through labor allocation (von Braun et al., 1994). Dairy cows may increase total labor demands on the household, including the caregiver for the children (or the children themselves in some cases). This has the potential to negatively affect the level of care and feeding provided by the caregiver (Huffman, 1987), in part through additional energy and protein demands worsening the nutritional status of the care giver. If the household makes use of hired labor to provide the additional labor necessary to care for the cow, impacts on the children and caregiver may be limited. In addition, the presence of livestock increases the probability that children and other household members contract animal-borne diarrheal diseases (Grosse, 1998a)[6] and other zoonotic diseases (such as tuberculosis), which would negatively influence both health and nutritional status.

Thus, the ownership of dairy cows can have both positive and negative impacts on child nutritional status, depending on which pathways dominate. This conceptual framework suggests that the ultimate outcome is in essence an empirical question. It also indicates that the impacts of dairy cow ownership on child nutrition overlap to a large extent with a number of larger development themes: technology adoption, commercialization of semi-subsistence agricultural production, and intra-household (gendered) distribution of work, income, and food.

What does the existing empirical evidence about dairy cow ownership imply about the linkages among the variables? Key relationships include the role of dairy consumption in child nutrient intake, the allocation of milk production between sales and household consumption, the

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[6] The evidence for cattle ownership *per se* and diarrheal diseases is less clear. Grosse (1998a) notes that Carstensen et al. (1987) reported that cattle herding communities in Guinea-Bissau are at higher risk of cryptosporidium diarrhea.

relationship between income, food expenditures, and household nutrient availability, and household labor allocation. Much of the evidence concerning the impact of milk consumption on child growth comes from studies that compare mean nutritional outcomes for groups of children consuming different amounts of milk, but with limited control of other factors. For example, Walker et al. (1990) found that stunted children in Jamaica consumed fewer dairy products than non-stunted children, and Seireg (1992) noted that children in Nicaragua who had consumed milk on the previous day were less often stunted than those who had not consumed milk. Kassouf (1991) found that children consuming milk had higher mean height-for-age status than children not consuming any milk among a sample from rural and urban Brazil, controlling for a variety of other effects. In a controlled intervention feeding trial, primary school children in Kenya receiving a snack including 200 or 250 ml of milk per day did not grow faster than children in a control group (Global Livestock CRSP, 2002).

Nicholson et al. (1999) noted that in coastal Kenya the increased milk produced by households with dairy cows resulted in increased milk sales with small increases in milk consumption. This provides circumstantial evidence that the primary impacts on child nutrition may be indirect, i.e., through increased income and changes in allocation of land and household labor. Huss-Ashmore (1993) indicated that the contribution of milk to household macronutrient availability was small, but could be notably more important if milk were provided preferentially to children. In addition, she determined that price relationships for maize and milk in coastal Kenya in the early 1990s were such that households could increase energy and protein availability by selling milk and purchasing grains and pulses. This latter result also suggests that indirect effects may be more important than increased milk consumption. However, this calculation does not consider that the bioavailability of protein and micronutrients found in milk (especially vitamins A and B_{12}) is better than that in grains and pulses.

Most studies have found that ownership of dairy cows increases household income, sometimes substantially (e.g., Leegwater et al., 1991; Mugo, 1994; Mullins et al., 1996; Nicholson et al., 1999). However, many previous authors have noted that the linkage between increases in income and nutrient consumption may be weak due to increasing expenditures on non-food items, increases in the costs of nutrients purchased, and shifts in income control (Behrman, 1988; Bouis, 1994; Kennedy, 1994). These “leakages” suggest that even if dairy cow ownership increases incomes, this may not significantly improve child nutritional status. However, Alderman (1994) noted that dairy producers increased milk sales, but also energy consumption and protein consumption in response to the presence of dairy marketing cooperatives in Karnataka, India. In the Ethiopian highlands, ownership of crossbred cows resulted in statistically significant increases in household income and caloric intake (Ahmed et al., 2000). Moreover, although non-food expenditure elasticities were higher than those for food expenditure, there was a moderate positive response of caloric intake to income.

The impacts of dairy cow ownership on household labor allocation (and their relationship to gender roles) may be important determinants of child nutritional status. Consistent with much of the literature on both technology adoption and commercialization of smallholder agriculture, there have been concerns about the effects of dairy production on the workload of women and children. A number of studies have suggested that dairy cow ownership increases time allocated to cattle-related tasks, especially in the cut-and-carry forage systems promoted under the NDDP in Kenya (Mugo, 1994; Maarse, 1995; Mullins et al., 1996). However, a more detailed study of time allocated to cattle-related tasks found that in coastal Kenya much of the additional effort required was performed by hired labour (Nicholson, 1999). The extent to which increased time allocated to cattle have affected time allocated to food crop production, other income-generating activities, or the quality or quantity of care and feeding for children is uncertain in the absence of information about overall time allocation by all household members (Tangka et al., 2000). Thus, changes in labor allocation due to dairy cow ownership have indeterminate *a priori* effects on child nutritional status.

THE STUDY AREAS

This study uses household-level data collected in two contrasting regions of Kenya, three districts in the lowlands of Coast province and two districts in the highlands. The coastal districts represent low agricultural potential areas, where dependence on non-agricultural income is high and the productivity of dairy cows lowered by high temperatures, humidity, and disease challenge. The highland sites generally represent those of greater agricultural potential, higher population density, and more favorable climatic conditions for dairy cows. Each of these sites is described in additional detail below.

COAST DISTRICTS

Coast Province covers over 80,000 square kilometers 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 kilometers 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 centers.

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. 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 pasteurized 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 small holder dairy farms. Since the price liberalization 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 pasteurized 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).

HIGHLAND DISTRICTS

Data for this study were collected in Kangundo and Mwala divisions of Machakos district and in Bahati, Rongai, Molo and Njoro divisions of Nakuru district. Machakos is one of the ten districts in Eastern province. The district has an area of 5,818 square kilometers and is subdivided into six divisions. Nakuru district is one of the fourteen districts in the Rift Valley Province. The district has an area of 7,200 square kilometers and is subdivided into ten administrative divisions. The population in Machakos district was estimated to be 960,000 in 1996, based on estimated annual growth rates of 3.0%. The divisions within high potential zones such as Kangundo have a higher population than the divisions in low potential zones. Nakuru district was estimated to have an annual growth rate of 5% in recent years, and a population 12.0 million in 1996. Nakuru municipality has the highest density with 2,358 people and also the highest population growth rate.

Rainfall in Machakos district varies with altitude. Total annual rainfall ranges from slightly over 1,000 mm in some of the highlands to slightly less than 500 mm in the low-lying areas. The rainfall pattern is bimodal with the long rains occurring between March and May, whereas the short rains fall from October to December. However, annual rainfall is quite variable. Temperature varies between 20° C and 25° C throughout the year. The coldest month is July and the warmest is October and March prior to the rains.

Climatic conditions in Nakuru district are strongly influenced by altitude and physical features such as escarpments, lakes and volcanic peaks. There is considerable variation in climate throughout the district. The long rains fall between the months of October and December. The amounts received vary from one year to another and influence greatly the crop yields in the district. The total annual rainfall ranges from 760 mm to 1,270 mm. The maximum temperatures are less than 30° C whereas the minimum is about 10° C. The hottest months in the district are January to March.

Agriculture is a major economic activity in Machakos district. Maize is the principal crop followed by pigeon peas, green grams, sorghum and cassava. The main cash crop is coffee. Other cash crops are cotton, French beans, and Asian vegetables. Livestock rearing is a major economic activity in the district with cattle and goats being the main livestock animals. The small-scale farm sector is the most important contributor of most livestock rearing products compared to the large-scale sector (ranches). Poultry, dairy and bee-keeping have recently become more common activities. Other primary production activities include fisheries, agro-forestry and sand harvesting.

Nakuru district is an agriculturally-oriented district with most of the population depending on agriculture and livestock for income and employment. The leading food crops include maize, beans, wheat, potatoes and various fruits and vegetables. Cash crops grown in the district include tea, coffee, pyrethrum and flower production. The district is also a leading producer of milk and beef, with production by about 130,000 smallholders. Forestry and fisheries are the other primary production activities.

METHODS

The analysis herein derives from the theoretical framework of agricultural household models (Singh *et al*., 1986; Alderman et al., 1994). These models assume that households maximize utility (according to a single set of preferences in the "unitary" model or multiple preferences in the "collective" models) subject to constraints on total income, time available, production technologies, and available land and capital. In addition, an implicit nutritional status production function is assumed, and the nutritional status of the household's children enters positively into the household's utility function. This implies that households have a demand for the nutritional status of the household's children, in a manner similar to its demand for other goods such as food, leisure time, and non-food goods.

The mathematical expression of the model is:

$$\max U = U(X^a, X^m, X^l, Z^{HH}, Z^{head}, N^k)$$

subject to:

$$\sum_m P^m X^m + \sum_h P^h X^h + w^{Hired} L^{Hired} \leq P^a (Q^a - X^a) + w^{Non-farm} L^{Non-farm} + E$$

$$T = X^l + L^{Non-farm} + L^{Family} + H$$

$$Q^a = Q^a(L, A, K, DC, LC) \qquad (1)$$

$$L = L^{Family} + L^{Hired}$$

$$N^k = N(X^a, X^h, H; Z^{HH}, Z^{child}, Z^{head})$$

where:

X=Consumption (a=Agricultural; m=Not produced by household; l=leisure; h=health inputs)

Z=Exogenous characteristics (HH=Household; $head$=Household head; $Child$=Child)

P=Price (m=Not produced by household; a=Agricultural; h=Health inputs)

Q^a=Production of agricultural good (e.g., milk)

w=wage rate (Non-farm and Hired)

L=(Labor allocated to agricultural activity, L=Total, *Family* and *Hired*)

T=Total household time available

H=Family labor allocated to child care and feeding

E=Exogenous income (e.g., gifts and remittances)

A=Land Area owned by the household

K=Capital Assets

DC=Dairy cows owned by the household

LC=Local cows owned by the household

N^k=Nutritional status of kth child in the household

This model is not solved or estimated directly. Rather, it provides guidelines as to the variables that influence child nutritional outcomes and whether these variables are exogenous (not determined by household decisions) or endogenous (determined by household decisions). This latter distinction is important, because it affects the nature of the econometric estimation procedures. A reduced-form version of the model, which includes all relevant exogenous variables, is estimated to determine the impacts of the number of dairy cows owned on the child nutritional outcomes N^k. These models are interpreted as reduced-form demand equations for the child nutritional status. In contrast, other studies estimate health or nutrition production functions, which differ in that they include endogenous variables (e.g., nutrient intake) that provide additional insights into how N^k is determined (Kassouf, 1991). Reduced-form demand equations provide insights about the ultimate relationships between the exogenous variables and child nutritional status, but provide limited information about the structural relationships (or pathways) that generate these outcomes. Note that these reduced-form models do not depend on whether the "unitary" versus "collective" household model is assumed (Deolalikar, 1996). In many prior studies, child morbidity is included as an explanatory variable for child nutritional status (Bouis and Haddad, 1990; Randolph, 1992). Because morbidity is assumed to be simultaneously (endogenously) determined with child nutritional status, it is not included in the reduced-form equations. Thus, the estimated impacts of dairy cow ownership on nutritional outcomes implicitly include any indirect effects of dairy cows on child morbidity.

This first set of reduced-form estimations addresses whether dairy cow ownership has a statistically significant impact on child nutritional status. The reduced-form equations for N^k are of the form:

$$N^k = N(Z^{child}, Z^{head}, Z^{household}, P^m, P^a, P^h, w, A, K, DC, LC, E) \qquad (2)$$

In a number of previous studies, a system of recursive equations has been used to estimate the impacts of production technologies or agricultural commercialization on income, income on food expenditures, food expenditures on nutrient availability, and nutrient availability on nutritional status (Bouis and Haddad, 1990; Ahmed et al., 2000). This sequence of equations provides insights about the pathways by which technology or market orientation influences child nutritional status. Because information on food expenditures and nutrient intake was not available for all households in our sample, a second set of "quasi-reduced form" estimations is used to provide additional information about selected pathways between household decisions and child nutritional status. These equations include predicted values of household cash income in addition to the exogenous variables. Because decisions by the household on the optimal levels of income, Y, and the level of N^k are simultaneous, we must estimate a quasi-reduced form model such as the following:

$$N^k = N(Z^{child}, Z^{head}, Z^{household}, P^m, P^a, P^h, w, A, K, DC, LC, E, \hat{Y}) \qquad (3)$$

where

$$\hat{Y} = Y(Z^{head}, Z^{household}, P^m, P^a, P^h, w, A, K, DC, LC, E) \qquad (4)$$

Following the approach employed by Randolph (1992) to explore agricultural commercialization impacts on nutrition in Malawi, two alternative econometric specifications are used to examine the impact of the variables of interest on child nutritional status: Seemingly Unrelated

Regression (SUR) models and Random Effects models (REM). The child nutrition model uses observations on individual children, and the basic econometric formulation for the model is:

$$N_{ik} = \sum_{r=0}^{R} \beta_{ir} X_{rk} + \varepsilon_{ik} \; ; \; \varepsilon_{ik} \sim iid\ N(0, I_{KT}\sigma_{\varepsilon}^{2}) \tag{5}$$

where i refers to the anthropometric indicator (i = 1, 2) and k to the child, the subscript r to the rth explanatory variable (with X_0 equal to a vector of ones). If errors are assumed to be uncorrelated across nutritional indicators, or the explanatory variables are the same in the equations for both indicators, the appropriate estimator is OLS. However, the use of OLS ignores the panel nature of the data, and the assumption of no correlation between error terms across indicators is contradicted by both theory and empirical findings (Randolph, 1992).

Hence, an alternative model can be specified as:

$$N_{ik} = \sum_{r=0}^{R} \beta_{ir} X_{rk} + \varepsilon_{ik} \; ; \; \varepsilon_{ik} \sim iid\ N(0, \Sigma \otimes I_{KT}) \tag{6}$$

to account for the contemporaneously correlated disturbances across equations for each nutritional indicator. Zellner's SUR estimator uses information about the expected cross-equation correlations, and can provide improvements in efficiency. However, because this estimator is identical to OLS when the explanatory variables used in each equation are the same if there are no cross-equation parameter restrictions, a two-step approach is used to estimate the SUR models. In the first step, the equations for two nutritional indicators are estimated by OLS with the full set of explanatory variables. Then, a subset of variables with t-statistics greater than or equal to one was selected for use in the SUR model estimation. This process removes different (statistically insignificant) variables from each equation, and implies that the SUR estimator will differ from OLS.

However, the SUR formulation still does not account for the panel nature of the data. The availability of multiple observations (i.e., children) for some households provides an opportunity to control for factors and characteristics ("effects")[7] not captured by the explanatory variables, but that contribute to heterogeneous responses between units of analysis at each level. To account for these types of effects, the model can be written as:

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[7] One such unobserved effect is the genetic endowment of the individual child. However, only household-level random effects are controlled for here.

$$N_{ik} = \sum_{r=0}^{R} \beta_{ir} X_{rk} + \gamma_{ik} + \varepsilon_{ik} \; ; \; \gamma_{\mathrm{h}} \sim iid \; N(0,\sigma_h^2) \text{ and } E(\gamma_{\mathrm{h}} \mid X_{rk}, \varepsilon_{ik}) = 0 \qquad (7)$$

This formulation is the random effects model, which assumes that household-level effects vary randomly between households but are constant for observations from individual households. Random effects can then be merged with the error term, and the appropriate estimator is GLS. The random effects model is preferred here over the alternative fixed effects model because the latter eliminates all explanatory variables that are invariant by household—including the variables of interest. Ideally, it would be desirable to combine the two model formulations to account for contemporaneously correlated errors across equations and random effects, but reported results herein are for the models estimated separately .

DATA

Data to estimate the models described above were collected in each of the two regions, using similar data collection instruments and procedures. At the coast, a sample of N=198 households was selected in three districts of Coast province (Kwale, Kilifi, and Malindi) and 172 households in the Highland districts. For the Coast, the sampling frame was based on a census of all households in those districts owning dairy cows. 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 cows. A total of 73 households with dairy cows were selected at random from the census of 719 households. Households without dairy cows were selected randomly from lists of 20 neighbours provided by each dairy-cow owning household. The sample of households for this survey was stratified by dairy cow ownership and division (the administrative unit below the district) 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 crossbred cow. Of these 184 households, 125 had children less than 72 months of age currently resident.

For the Highlands, data collection followed methods employed in a previous effort conducted in nine districts of Kenya. Ninety-two administrative divisions (sub-locations) in nine districts were selected for the previous study, and survey maps for each location were developed based on available GIS databases. Transect lines were drawn across two randomly-chosen landmarks, and every fifth household on the left and right alternately were selected for the sample. All sample households in the Machakos and Nukuru districts provided an initial sample for this study. Of these households, 177 with children aged 6 to 59 months were surveyed. The sample was divided among households with at least one dairy cow (87 households), those who owned only local cattle (16 households) and those who did not own any cattle (74 households). As at the Coast, a structured questionnaire was administered to these households during February to May 1999.

Exogenous and endogenous variables used in the regression analyses are summarized in Table 1. These variables include child characteristics, household head characteristics, and household characteristics. Child specific characteristics include age, sex, and birth order. Previous studies have found many of these variables to be statistically significant determinants of nutritional status (e.g., Kennedy, 1994, Haughton and Haughton, 1997; Tharakan and Suchindran, 1999). Linear and quadratic terms were included for child age based on patterns of mean nutritional status at various ages. The household head was the person identified by the survey respondent as the head of household. Household head characteristics include age (linear and quadratic terms), sex, and years of education. These variables reflect the human capital accumulation of one of the household's key decision makers. For the highlands data, years of education was constructed based on categorical responses. 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. Thus, a dummy variable was specified for the religious affiliation of the household head. At the coast, this dummy took the value of one for households in which the head was Muslim, and in the highlands (where there were no Muslims in the sample), a value of one indicated that the head was protestant (rather than Catholic or Seventh Day Adventist). An ethnic group dummy was specified in both regions, given the relationship between ethnicity, cattle ownership and milk consumption. At the coast, a value of one indicated that the household was a migrant to the coast. 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 was a migrant is relevant to cattle ownership and management decisions. In the highlands, a value of one indicated that the household head was Kikuyu.

The amount of land owned by the household will influence its production and allocation decisions, and therefore may influence child nutritional status. Moreover, the formality of tenure status for the land may also influence production decisions, so a dummy variable indicates whether or not the household has a title deed for its land. Household demographic factors will also affect observed nutritional outcomes. To capture this effect, the dependency ratio (number of household members divided by the number under age 16) is included as an explanatory variable. Price variables include the milk price, as indicated by the household based on transactions from either of two sources: the latest transaction reported by the household during period immediately prior to the survey, or, if the household did not buy or sell during the last four months, the price at which the household believed milk or maize could be sold as of the survey date. The milk prices are considered exogenous because the market-level impacts of dairy cow ownership by a household are assumed to be negligible[8]. Data on other prices and wage rates were not available for the highland districts.

Gift and remittance income is assumed to be exogenous to the household, and is counted among the other resources available to the household. A district-level dummy variable is included for each of the regions. For the coast estimations, this variable has the value one if the household was located in Kwale district, which has higher disease challenge, fewer non-agricultural employment opportunities, and less well developed transportation infrastructure. For the highland models, this dummy distinguishes between the two districts, taking the value of one for Machakos. These dummy variables capture a broad spectrum of effects, including access to health facilities, human and animal disease occurrence, transactions costs and infrastructure to support agricultural production and marketing. A dummy variable for water supply was included in the coast equations, and had the value one if the household's source was a pipe or well. The total number of local cattle are included as proxies for wealth and to examine whether cattle ownership per se has nutritional impacts. A focal point for this study, of course, is the number of dairy cows (defined as grade or crossbred animals) owned by the household. The number of

[8] This is in contrast to the importance of market-level impacts of dairy cooperative development in India analyzed by Alderman (1994).

cows is assumed to be predetermined. 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[9] supporting exogeneity. The number of dairy cows is therefore treated as an exogenous variable.

Household cash income is used in the development of the "quasi-reduced form" models. As Behrman (1988) and others have noted, it is common in empirical studies to use household cash income rather than the more theoretically appropriate "full income" concept. The latter includes the value of leisure time and goods produced and consumed by the household, whereas the former does not. Small changes in leisure time or food sales may change cash income substantially although they have little impact on full income. In addition, expenditure data, rather than income *per se*, is often used in child nutrition studies because it is assumed to better represent permanent rather than transitory income and because it is often more accurately collected than income data (von Braun et al., 1994). Dairy production consumption per adult equivalent, although not included in the econometric estimations, is shown in the descriptive statistics (Table 1).

The dependent variables in the econometric models are two anthropometric measurements commonly as indicators of nutritional status for households in societies with significant levels of protein-energy malnutrition (Low, 1991; Quinn, 1992). Children are measured because they are presumed to be the most vulnerable members of the household, and thus provide a sensitive indicator for the household as a whole. The interpretation of anthropometric measurements is also easier for pre-school children than for older members of the household because there are fewer genetic differences among pre-school children in different ethnic groups and reproductive status of females can be ignored. The measures typically used include 'weight-for-height' and 'height-for-age'. A low value of weight-for-height indicates that the child is very thin for his or her stature, and thus provides a measure of acute malnutrition (often referred to as 'wasting'). A low value of height-for-age indicates that the child is shorter than one would typically expect for a child of the same age because of the accumulated effect of periods of morbidity and inadequate food intake (often referred to as 'stunting'). The measures are typically converted to z-scores

[9] In a simultaneous equations model, a t-test of the coefficient for $\psi=\sigma_{12}/\sigma_2^2$ 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 with nutritional outcomes.

(the number of standard deviations from the mean of a reference population) using the U.S. National Center for Health Statistics (NCHS) growth percentiles as a reference (WHO, 1983). Because they are standardized measures, the z-scores can be compared for different age groups and for the two indicators of nutritional status (Quinn, 1992).

Anthropometric data for individual pre-school aged children and other child-specific data were collected from 125 households in three districts of coastal Kenya and from 1777 households in the highlands (Table 2). Data were collected consistent with protocols established by the Central Bureau of Statistics of Kenya (who conduct annual regional nutritional surveys) and the Ministry of Health of Kenya, which operates field clinics in coastal Kenya. Staff from each of these government organizations participated in data collection. The anthropometric measurements for 119 children less than 61 months of age and 33 additional children between 61 and 72 months of age obtained in the field surveys of were used to calculate 'height-for-age' (HAZ) and 'weight-for height' (WHZ) z-scores for each child[10]. Because the sample size at the coast was small, the observations for these older children were included in the econometric models, although it is common practice to include only children less than 60 months of age. Although some studies exclude children under six months of age (particularly studies examining food intake), they were included in our analyses because it is conceivable that cattle ownership may have an influence on female time allocation and other factors that can influence the nutritional status of infants.

RESULTS

DESCRIPTIVE RESULTS

Although not definitive indicators of the impacts of dairy cow ownership, differences in child and household characteristics by region or cattle ownership category can provide insights into the nature of the information used in econometric modeling, and thus aid in the interpretation of the results. We will consider first the differences between regions, somewhat independently of whether the household owns a dairy cow. One notable difference involves the developmental stage of the households (Table 1). Households in the highlands appear to be younger, as indicated by differences in the mean birth order for the children, mean age of the children, mean age of the household head, and the household dependency ratio. In addition, the proportion of

[10] Z-scores compare the individual child to a reference population of the same age and sex, where z indicates the number of standard deviations away from the mean of the reference population. Low z-scores for height-for-age indicate chronic malnutrition; low z-scores for weight-for-height indicate acute malnutrition.

female-headed households is larger in the highlands. The mean number of years of education for the household head is lower in the highlands, perhaps reflective of higher returns to agricultural production than at the coast. Consistent with higher population densities in the highlands, the amount of land owned by the households is lower there. However, the proportion of households with formal title to the land they farm is also lower in the highlands. Previous studies have indicated that farm milk prices are higher at the Coast (Staal and Mullins, 1996), and this pattern is observed in our data as well. The number of local cattle owned is smaller in the highlands, consistent with smaller farm sizes and generally higher agricultural potential. The number of dairy cows owned by households owning at least one is more than twice as high in the highlands than at the coast, and milk consumption per adult equivalent is substantially higher. Household incomes are roughly comparable in the two regions for households without dairy cows, but are somewhat higher at the coast for households with dairy cows.

Differences among households with different cattle ownership status provide an initial indication of factors potentially influencing child nutritional outcomes. At the coast, households owning dairy cows had a higher proportion of male household heads, a higher proportion of migrant ethnic groups (Table 1). These households owned more land on average, although this may also result from the lower mean agricultural productivity of land at the coast and the impact of administrative settlement schemes that provided 12-acre plots. A higher proportion of households with dairy cows had a formal title to their land compared to households without cattle. Households with dairy cows reported a lower milk price than households owning only local cattle. This may reflect price differences between milk producers and milk consumers due to transactions costs, although many milk sales are direct from producer to consumer. These price differences may also indicate differences in the location of households owning dairy cows, local cattle, and no cattle. Gift and remittance income was higher for dairy cow-owning households, and total cash income was markedly higher for households with dairy cows. The proportion of households with piped or well water was highest for households with only local cattle (46%), whereas it was half that percentage among households with dairy cows. Ownership of dairy cows implies lower numbers of local cattle are owned, which suggests that the two types of animals are viewed as substitutes. Dairy consumption per adult equivalent was higher for households with dairy cows, although consumption levels are relatively low (less than one liter per week).

In the highlands, the pattern among households of the three cattle ownership categories differs from that at the coast. In the highlands, the age of the household head differs for local cattle owners and other households, as does the proportion of household heads belonging to the Kikuyu ethnic group. Households owning any cattle owned more land than households without cattle, but a higher proportion of households with dairy cows held a formal title to their land. The mean dependency ratio was higher for households owning cattle, but the absolute magnitude of the difference was small (0.11). As at the coast, the mean milk price received was lower for households owning dairy cows, which again may reflect both transactions costs and the presence of dairy cow-owning households in locations with greater market access. As at the coast, dairy cow-owning households owned few local cattle, due to smaller landholdings and a larger number of dairy cows owned. Both household income and dairy consumption per adult equivalent are significantly higher for dairy cow owners.

Indicators of child nutritional status differ by region and cattle ownership status (Table 2). Mean WHZ scores differ little between the coast and the highlands, although the percentage of children experiencing moderate-to-severe wasting is higher at the coast. Consistent with previous reports (Leegwater et al., 1991; Foeken et al., 1995) wasting affects a significant proportion of children in both regions, more than 10% of children in households owning only local cattle at the coast. A similar pattern is noted for mean HAZ scores: regional means differ little, but the proportion of children with moderate-to-severe stunting is higher at the coast. Again consistent with previous studies (Foeken et al., 1995), the proportion of children with at least moderate stunting is large—more than one-third of children measured in each region. In the highlands, dairy cow owners had a higher mean WHZ than households owning only local cows, but not households with no cattle. At the coast, households with dairy cows had a higher mean HAZ than households with without cattle, but there was no significant difference with households owning only local cattle. Dairy cow-owning households in the highlands had a higher mean HAZ than households without cattle. Thus, cattle ownership status may be associated with differences in mean z-scores, but the patterns do not indicate a clear advantage for households with dairy cows compared to all other households. Moreover, the overall distribution of both WHZ and HAZ categories does not differ by cattle ownership status based on standard χ^2 tests. These results provide preliminary evidence that dairy cow ownership *per se* may not have large effects on child nutritional status.

IMPACTS OF CATTLE OWNERSHIP ON CHILD NUTRITION

A number previous studies of the impact of cattle or livestock ownership on child nutritional status have employed binary (i.e., zero or one; Vella et al., 1995) or categorical variables (e.g., Grosse, 1998b) to represent ownership status. Although subsequent analyses will include the number of cows or cattle owned by breed type, it is useful to employ a binary variable approach to make the results of the current study more comparable to previous ones. As noted previously, the impact of cattle ownership (and dairy cow ownership) on child nutritional status is estimated using three types of reduced-form econometric models. These models represent the household-level (reduced-form) demand for child nutritional status as a function of child characteristics, characteristics of the household head, and household characteristics. Thus, they provide limited information about the pathways by which cattle or dairy cow ownership affects nutritional status. Rather, they indicate the aggregate outcome of the various pathways (Figure 1) on the demand for nutritional outcomes. Two key questions are: 1) what is the overall impact of cattle or dairy cow ownership on child nutritional status, and 2) what other factors influence child nutritional status, either negatively or positively?

Consistent with the results of Vella (1995) and Grosse (1998b), ownership of cattle has a statistically significant positive effect on the mean height-for-age Z-score (HAZ) for children in the coast sample for all three model specifications (Table 3; complete results are reported in Appendix Tables 3 and 4). The effects range from 0.55 to 0.85 standard deviations, which are large compared with the findings of Vella (1995) and Grosse (1998b). For the highland sample, the cattle ownership has positive effects on HAZ similar in size to those reported by Vella (1995) and Gross (1998b), 0.29 to 0.36. If the binary variable for cattle ownership is separated, with one binary variable for local cattle ownership and a second for dairy cattle ownership, the effect of local cattle is strong and positive, and the dairy cattle ownership variable is statistically insignificant (results not reported herein). This suggests that ownership of local cattle may have a stronger positive effect on HAZ than ownership of dairy cattle, but does not make clear why this occurs. Cattle ownership does not have a statistically significant impact on mean weight-for-height Z-score (WHZ) for any model formulation in either region. Overall, these results suggest that cattle ownership has potentially large positive impacts on longer-term child nutritional status (growth) but little or no impact on short-term nutritional status. This outcome may arise from the role of cattle as assets that can help to mitigate various nutritional shocks over time, but our approach does not allow explicit examination of this hypothesis.

IMPACTS OF DAIRY COW OWNERSHIP ON CHILD NUTRITION

Analyses of the impacts of dairy cow and local cattle ownership use the numbers of each type of animal owned, rather than binary variables. The number of dairy cows owned by a household has no statistically significant effects on wasting (WHZ) in the two model formulations, either at the coast or in the highlands (Table 3). The coast models indicate a negative but statistically insignificant relationship, and for the highlands, the estimated coefficients are near zero and statistically insignificant. Dairy cows owned has a statistically significant positive impact on stunting (HAZ) for the SUR model estimated with the coast data. Estimated coefficients for the REM coast models and for the highlands are positive but not statistically significant. The estimated coefficients are much smaller for the highlands, which may reflect greater availability and lower prices of milk whether the family owns a dairy cow or not (recall that milk consumption for households in the highlands is substantially higher than for households with dairy cows at the coast). To the extent that the SUR model accurately captures impacts on HAZ at the coast, the impact on child nutritional status is non-trivial. The estimated coefficient implies that ownership of one cow would increase the nutritional status of children in the household by 0.26 standard deviations, with all other variables evaluated at the mean of the data. In practical terms, this implies that if all households owned the mean observed level of 1.69 cows per household, the percentage of children with moderate or severe stunting would be reduced from 54% to 32% for households currently owning no cattle. For households owning only local cattle, ownership of the mean number of dairy cows would reduce the percentage of moderate-to-severely stunted children from 36% to 22%. This is not to suggest that provision of dairy cows alone would have these effects, but they provide a context in which to interpret the estimated impact of dairy cow ownership on HAZ at the coast.

These empirical results are roughly consistent with Hitchings (1982) who found that in three zones of highland Kenya, dairy cows had a statistically significant impact on HAZ but not on WHZ. Similarly, Grosse (1998b) found that for rural households in Rwanda, ownership of dairy animals had a statistically significant effect of a similar order of magnitude on HAZ, but did not report results for WHZ. These results suggest that dairy cow ownership has minimal impact on short-term nutritional status (indicated by WHZ), but that dairy cows may have a positive impact on long-term nutritional status (indicated by HAZ) at least in certain settings. Given the magnitude of the positive impacts of dairy cow ownership on household income and dairy product consumption, the lack of strong positive impacts implies either that the pathways relating household income or dairy product consumption with nutritional status contain significant "leakages," or that these pathways function but are offset by other negative effects (e.g., through labor allocation or disease transmission), or both. This highlights the need for additional information about the relationship among variables determining child nutritional status.

However, the finding of no overall negative effects of dairy cow ownership is relevant given concerns about tradeoffs in land allocated to forage versus food crops, zoonotic disease transmission and increased time allocated to cattle-related tasks (especially by women) when dairy cows are owned. In this sense, the results mirror those reported by Kennedy (1994) for cash crops more generally from a series of case studies on commercialization of agriculture. A key conclusion of these studies was that "none of the case studies reported…shows a clear negative effect of the commercial agriculture schemes on children's health and nutritional status." Thus, although dairy cow ownership *per se* may have small impacts on HAZ in some settings, there appear to be no negative impacts on either nutritional indicator.

Other factors that influence child nutritional indicators for the two models are reported in Appendix Tables 5 and 6. In general, the results from the two models are qualitatively similar. The complete set of coefficients suggests that variables influencing child nutritional status differ at the coast and in the highlands. For example, at the coast, birth order is positively related to WHZ, perhaps due to dynamic wealth accumulation effects, but this variable is insignificant for the highland sample. Moreover, the variables affecting WHZ differ from those affecting HAZ, as has been noted in a number of studies (Randolph, 1992; Kennedy and Haddad, 1994; Tharakan and Suchindran, 1999).

The variables used in this study control primarily for inherent characteristics of the children, the household head, and the household itself so that the impact of dairy cow ownership *per se* can be identified. As such, they provide primarily guidelines for areas of emphasis in future studies, rather than for how policies or programs might best bring about improvements in mean nutritional status. That is, these detailed results may raise more questions than they answer, such as "Why is the nutritional status of male children significantly lower than for female children?" or "What is the mechanism by which water supply improves nutritional status at the coast?"

These results alone provide limited information about the responses to these questions. As Kennedy (1994) noted with regard to female headship, it is often not a characteristic *per se* that imparts a nutritional impact, but a "complex interaction" of numerous factors including that characteristic, expenditure patterns, and time use. However, the questions arising from consideration of these results may be useful in the design of more detailed and focused studies of the pathways influencing child nutritional outcomes.

The impacts of dairy cow ownership should be examined with reference to studies showing that consumption of dairy products positively influences child nutritional status (Neumann, 1998; Grosse, 1998a). As noted in Table 1, households with dairy cows consumed more milk than other households in both regions. Reduced-form econometric models (results not reported here) also indicated that the number of cows increases milk consumption, by 1.2 liters per adult equivalent per week in the highlands, and 1.6 liters per adult equivalent per week at the coast. Why does this increase in dairy product consumption not result in an improvement in child nutritional status? First, increasing overall household consumption may not result more milk being consumed by children, especially if higher milk production alters the allocation of milk among household members. Information on child-specific milk consumption was not collected as a part of this research. Second, the amount of the increase may be insufficient to have a marked impact on wasting or stunting, although Neumann et al. (2002) have pointed out that relatively small amounts of micronutrients in animal products may have synergistic effects on macronutrient status. Finally, the benefits of increased milk consumption by children may be offset by other factors such as time devoted to care and feeding, reductions in other foods provided to children, or diarrheal disease related to proximity to livestock. To the extent that increasing dairy consumption is a nutritional objective, these limited effects of increased dairy consumption suggest that strategies to achieve this objective must be carefully designed in order to have significant nutritional impact. Additional information on household nutrient allocation, labor allocation, and child morbidity would help to determine which strategies to increase consumption are likely to most benefit children.

IMPACTS OF INCOME ON CHILD NUTRITION

To explore the pathways by which dairy cow ownership may influence nutritional status, and to understand how the potential positive impacts may be enhanced, we examine the influence of an additional variable on child nutritional status: household cash income. This is important to understanding whether the increases in household income documented for dairy cow ownership are important determinants of child nutritional well-being, or whether leakages or other effects limit the nutritional benefits of higher incomes (a question raised in more general form by Berhman, 1988). Moreover, we can examine the impact of dairy cow ownership on child nutritional status controlling for the effects of ownership on income. This provides additional insights about how dairy cows influence nutritional outcomes.

Because household income is assumed to be simultaneously determined with child nutritional status, we used a variant of two-stage least squares to estimate predicted values for income using the other exogenous variables in the system. The predicted values for income were then used in "quasi-reduced" form equations to examine their impact on the demand for child nutritional status. Heteroskedastic Tobit estimation was used for the reduced-form equation for income because test for the presence of censoring and heteroskedasticity were statistically significant. The reduced-form estimations indicated that dairy cow ownership has a statistically significant positive impact on household cash income. At the coast, the marginal effect of each cow was between 2,115 and 3,488 KSh per month, and 965 KSh per month in the highlands, controlling for other factors and evaluated at the mean of the data. These impacts on income are large relative to income levels for households without cows, representing 63 to 116% of incomes for households without cows at the coast, and 30% of incomes for households without cows in the highlands. Thus, increases in income are one pathway by which dairy cow ownership may influence child nutritional status.

At the coast, the impact of income on WHZ is positive but not statistically significant in both models, and the estimated coefficients are small (0.0 to 0.05 standard deviations per 1,000 KSh/mo; Table 5). The small absolute magnitude of the response of WHZ to income at the coast may explain why improvements in short-term nutritional status are minimal despite large income increases resulting from dairy cow ownership. In the SUR model, the effect of dairy cows owned when the impact of ownership on income is controlled for may be negative[11] (i.e., the income effect may be positive but other effects associated with dairy cow ownership may work in the opposite direction). A negative effect would be consistent with the hypothesis that dairy cows influence labor allocation or an increase the incidence of diahrreal diseases, but our analyses do not allow specific identification of these effects.

[11] The effect is significant only at the p=0.12 level.

For HAZ, there is no statistically significant impact of income at the coast or in the highlands, although most estimated coefficients are positive. There are a number of possible explanations for the limited impact of higher income on HAZ, including increased expenditures on non-food items and substitution for more expensive forms of calories and protein (von Braun et al., 1994). Kennedy (1994) has identified an additional dimension of this relationship: household awareness of growth stunting. Although households often can easily recognize low weight-for-height children, it may be more challenging to identify children growing more slowly than normal, especially when a household's children may look much like other children in the community due to the high proportion of stunted children. Thus, households may not perceive a nutritional problem and therefore do not alter expenditure patterns or intra-household nutrient allocations to address it. However, Huffman (1987) has argued that nutritional education can only improve nutritional status when income and nutrient availability are sufficient.

In the highlands, the impact of income on WHZ is negative and statistically significant in the SUR models (and nearly so for the REM; Table 5). This negative impact is counter-intuitive, and may be due in part to factors described in the previous paragraph. However, a number of other factors may be influencing this outcome. First, increases in cash income may be associated with decreases in household nutrient availability if food crops are sold and the money is used for non-food expenditures. This phenomenon can be related to gender control of income, as increases in cash incomes can result in transfer of control of the income from women (who tend to spend more on food) to men (Tangka et al., 2000). Moreover, increases in household cash income may be the result of increased wage employment or increases in the time required by adult females for agricultural activities. If either of these is true, higher household incomes may be associated with less time for child care and feeding, with negative nutritional consequences. In part, the negative impact of income in the highlands reflects the use of cash income rather than full income concept. Additional information on nutrient allocation, household expenditures, and labor demands on household members is needed to adequately interpret these results.

When the negative impact of income on WHZ in the highlands is accounted for, the impact of dairy cow numbers is positive and statistically significant in both the SUR and REM models (Table 5). The estimated effects of income and cow ownership controlling for income on WHZ are reversed in the highlands and at the coast. It may be that intra-household allocation patterns for increased milk production differ in the two regions, that labor allocation processes differ, or that dairy production complements other elements of the agricultural production system better in the highlands than at the coast. Again, our reduced-form models do not allow us to distinguish which of these alternatives underlies the estimated outcome.

The impacts described above underscore three points relating to income and nutritional outcomes in this context. First, if income effects on the demand for child nutritional status are minimal or negative, the benefit of higher income from dairy cow ownership is unlikely be reflected in marked improvements in child nutrition. Second, the pathways by which income effects arise—particularly negative ones—are in need of additional investigation. Third, the differences in income effects between the highlands and the coast suggest the need for site-specific study of nutritional impacts.

CONCLUSIONS AND IMPLICATIONS

Dairy cow ownership has been actively promoted in Kenya in the past, and a number of previous studies have suggested that ownership can increase household-level milk production, milk consumption, and cash income. These impacts suggest that there is potential for positive impact on child nutritional status, but competition between dairy cows and food crops for the land and labor available to the household may negatively affect child nutrition. Impacts of dairy cow ownership have been little studied to date. Thus, the principal objective of this study was to examine the impact of dairy cow ownership in two regions of Kenya on the nutritional status of preschool children.

Consistent with two previous studies, cattle ownership *per se* appears to have a positive impact on child growth, both at the coast and in the highlands. Whether the household owned cattle has no statistically significant impacts—positive or negative—on short-term nutritional status. The contrast between the general magnitude and significance of the results for cattle ownership and dairy cow numbers suggests the need for additional information by which cattle (whether local or dairy) results in improvements in nutritional status.

The impacts of dairy cow ownership on weight-for-height were minimal in both regions. At the coast, dairy cows appear to have a positive impact on long-term growth, as indicated by height-for-age z-scores. Impacts on growth in the highlands were minimal. These results imply that promotion of dairy cow ownership through dairy development programs are unlikely to have negative consequences for child nutrition, consistent with earlier findings about the impact of agricultural commercialization in the crops sector (Kennedy, 1994). However, these results also imply that the positive effects of dairy cow ownership on child growth may be limited to certain production and market settings. Limits on the positive growth effects may arise because linkages between income and the demand for child nutritional status are relatively weak, but may also be due to other factors not examined in this study. Clearly, additional information about the pathways by which dairy cow ownership and other factors influence child nutritional status—especially greater detailed information on the intra-household allocation of resources, income, and nutrients—would allow better informed interventions to enhance the nutritional benefits of dairy cow ownership. This is consistent with recommendation by Haddad (2000) that agricultural research designs should include elements to enhance positive nutritional impacts.

Given the differences between the regions in this study, household-level nutritional impacts appear to be site-specific. It is likely that there is no definitive answer to the question of whether dairy cow ownership has nutritional benefits for children. That is, the nutritional impacts will vary based on how dairy cow ownership changes key factors such as land and labor allocation, control of income and expenditures on food, and child morbidity. As von Braun et al. (1994) noted for agricultural commercialization, the challenge is to examine impacts in specific contexts, identify factors that enhance or reduce nutritional outcomes, and use this information to provide guidance for program and policy formulation.

In the face of results indicated limited effects of dairy cow ownership on WHZ and site-specificity of positive impacts on HAZ, it is tempting to focus on alternatives to dairy cow ownership as a mechanism to increase the consumption of animal-source foods by pre-school children (e.g., school feeding programs, targeted powdered milk subsides). However, dairy cow ownership provides other benefits to the household and the local community (e.g., higher, more regular cash income, employment generation, and greater milk availability; Nicholson et al., 1999). Additional efforts to improve understanding of the pathways by which dairy cow ownership influences nutritional outcomes may allow identification of interventions that enhance the nutritional benefits of dairy cow ownership while preserving the non-nutritional benefits. For example, medical personnel in coastal Kenya opined that nutritional education programs designed to improve household awareness of the prevalence of stunting and increase the allocation of milk to children may be an effective way to enhance the nutritional benefits of dairy cow ownership. Further analyses of the role of livestock in child nutritional status can benefit from study designs that include multiple observations over time. Such designs would improve the ability to account for seasonal effects (Hoorweg et al., 1995) and growth rather than achieved growth status (Deolilakar, 1996). Moreover, they would provide insights into the dynamic and cumulative effects of cow ownership on household welfare that cross-sectional studies such as this one shed only limited light upon.

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Table 1. Descriptive Statistics for Sample of Children and Households Used in Econometric Analyses of Nutritional Impacts, By Cattle Ownership Status

		Coast Districts			Highlands Districts		
		None	Local	Dairy	None	Local	Dairy
Child Characteristics							
Birth Order	Mean	4.20	4.32	3.57	2.92[a]	3.79[a]	3.22
	s.d.	2.59	2.48	2.19	1.50	1.47	1.63
Sex (1=Male, 0=Female)	Mean	0.47	0.54	0.50	0.53	0.58	0.55
	s.d.	--	--	--	--	--	--
Age, months	Mean	42.61	35.36	42.00	30.16	30.11	31.80
	s.d.	18.20	18.47	19.92	14.68	12.31	14.78
Household Head Characteristics							
Age, years	Mean	52.04	53.70	51.64	40.47[ab]	51.58[ac]	44.96[bc]
	s.d.	12.87	13.99	12.61	12.03	14.26	12.73
Sex (1=Male, 0=Female)	Mean	0.90[b]	0.93	0.98[b]	0.83	0.89	0.84
	s.d.	--	--	--	--	--	--
Education, years	Mean	3.76	3.36	5.02	1.43	1.68	1.38
	s.d.	4.11	4.52	4.79	0.87	1.11	0.93
Religion dummy[1]	Mean	0.47	0.29	0.34	0.59[b]	0.68	0.73[b]
	s.d.	--	--	--	--	--	--
Ethnic group dummy[2]	Mean	0.04[b]	0.04[c]	0.16[bc]	0.52[a]	0.16[ac]	0.53[c]
	s.d.	--	--	--	--	--	--
Household Characteristics							
Land area owned, ha	Mean	5.43[ab]	10.30[c]	15.56[bc]	2.42[ab]	8.37[a]	6.09[b]
	s.d.	4.78	5.42	13.84	3.36	8.16	7.35
Tenure Status (1=Title deed, 0=No title deed)	Mean	0.63[ab]	0.89[a]	0.95[b]	0.48[b]	0.42[c]	0.65[bc]
	s.d.	--	--	--	--	--	--
Dependency ratio	Mean	2.45	2.17	2.37	1.41[ab]	1.58[a]	1.52[b]
	s.d.	0.79	0.77	2.09	0.31	0.33	0.41
Milk price, KSh/liter	Mean	27.74	29.77[c]	25.65[c]	21.72[ab]	25.65[ac]	17.34[bc]
	s.d.	6.35	6.27	7.67	5.94	7.82	5.33
Gift and remittance income, KSh/mo	Mean	56.39[b]	24.40[c]	228.21[bc]	240.40	289.47	224.41
	s.d.	245.37	118.22	534.81	621.70	618.82	597.05
Water dummy[3]	Mean	0.00[ab]	0.46[ac]	0.23[bc]			
	s.d.	--	--	--			
Total local cattle owned	Mean	0.00[ab]	8.04[ac]	2.14[bc]	0.00[ab]	5.00[ac]	0.46[bc]
	s.d.	0.00	4.62	3.21	0.00	5.12	1.41
Number of dairy cows	Mean	0.00[b]	0.00[c]	1.68[bc]	0.00[b]	0.00[c]	3.76[bc]
	s.d.	0.00	0.00	1.16	0.00	0.00	4.27
Endogenous Variables							
Total cash income, KSh/mo	Mean	3,323[b]	3,018[c]	9,987[bc]	3,467[b]	4,098[c]	7,161[bc]
	s.d.	2,879	2,616	8,205	3,097	3,120	8,903
Dairy consumption per adult, liters/week	Mean	0.37[b]	0.35[c]	0.97[bc]	1.84[b]	2.24[c]	6.45[bc]
	s.d.	0.42	0.45	1.42	1.42	1.93	7.75

[1] For Coast, 1=Muslim, 0=Other. For Highlands, 1=Protestant, 0=Catholic or Seventh Day Adventist.

[2] For Coast, 1=Migrant Ethnic Group, 0=Mijikenda. For Highlands, 1=Kikuyu, 0=Other.

[3] For Coast, 1=Piped water supply, 0=Well, roof catchment, river, or other. Data on water supply system not available for Highlands.

Note: Letters next to means indicate statistically significant differences at the 5% level among cattle ownership groups within the given region. Key:

a=no cattle and local cattle statistically significantly different
b=no cattle and dairy cows statistically significantly different
c=local cattle and dairy cows statistically significantly different

Table 2. Nutritional Status of Pre-school Children and Cattle Ownership Status, By Region

	Coast Districts			Highland Districts		
	No Cattle	Local cattle	Dairy Cattle	No Cattle	Local cattle	Dairy Cattle
Weight-for-height (WHZ)						
Mean Z-score	-.37	-.57	-.40	-.32	-.67[c]	-.20[c]
s.d.	1.16	1.37	1.24	.99	.97	.97
Number of Children	70	18	56	99	19	127
Percentage of children[1]						
Normal	72.9	72.2	76.5	74.7	57.9	84.3
Mild wasting	21.4	16.7	15.7	22.2	36.8	12.6
Moderate wasting	2.9	5.6	2.0	3.0	5.3	1.6
Severe wasting	2.9	5.6	5.9	0.0	0.0	1.6
Height-for-age (HAZ)						
Mean Z-score	-2.05[ab]	-1.01[a]	-1.57[b]	-1.71[b]	-1.24	-1.35[b]
s.d.	1.38	2.01	1.33	1.50	.82	1.23
Number of Children	70	28	53	99	19	127
Percentage of children[1]						
Normal	21.4	35.7	32.1	23.2	36.8	31.0
Mild stunting	24.3	28.6	30.2	32.3	34.6	34.7
Moderate stunting	31.4	28.6	22.6	29.3	21.3	24.1
Severe stunting	22.9	7.1	15.1	15.2	7.9	10.2

[1] Categories of wasting and stunting are based on z-scores, where $z > -1.0$ is normal, $-1.0 < z < -2.0$ is mild malnutrition, $-2.0 < z < -3.0$ is moderate malnutrition, and $z < -3.0$ is severe malnutrition (Quinn, 1992).

Note: Pre-school children are those 0-72 months of age for the Coast, 0-60 months of age for the Highlands.

Note: Letters next to means indicate statistically significant differences at the 5% level among cattle ownership groups within the given region. Key:

a=no cattle and local cattle statistically significantly different
b=no cattle and dairy cows statistically significantly different
c=local cattle and dairy cows statistically significantly different

Table 3. Estimated Impacts of Cattle Ownership[1] on Indicators of Child Nutritional Status, By Region

Model	WHZ		HAZ	
	Coast	Highlands	Coast	Highlands
SUR Models				
Coefficient	-0.11	0.04	0.55	0.29
s.e.	0.21	0.12	0.24	0.17
t-statistic	-0.50	0.32	2.26	1.67
REM Models				
Coefficient	-0.12	0.03	0.85	0.36
s.e.	0.37	0.15	0.40	0.21
t-statistic	-0.36	0.20	2.11	1.68

[1] Binary variable equal to one if the household owns local or dairy cattle and zero otherwise.

Table 4. Estimated Impacts of Dairy Cow Numbers Owned on Indicators of Child Nutritional Status, By Region

Model	WHZ		HAZ	
	Coast	Highlands	Coast	Highlands
SUR Models				
Coefficient	-0.05	0.01	0.26	0.03
s.e.	0.10	0.02	0.11	0.02
t-statistic	-0.52	0.90	2.42	1.47
REM Models				
Coefficient	-0.08	0.02	0.10	0.04
s.e.	0.16	0.02	0.18	0.03
t-statistic	-0.50	0.96	0.57	1.10

Table 5. Estimated Impacts of Household Cash Income on Indicators of Child Nutritional Status and Impacts of Dairy Cows Controlling for Household Income, By Region

Variable, Model	WHZ		HAZ	
	Coast	Highlands	Coast	Highlands
Household Cash Income, 000 KSh/mo				
SUR Models				
Coefficient	0.05	-0.10	0.04	0.00
s.e.	0.04	0.03	0.04	0.03
t-statistic	1.35	-2.92	0.94	-0.14
REM Models				
Coefficient	0.00	-0.07	0.00	-0.03
s.e.	0.00	0.05	0.00	0.07
t-statistic	0.45	-1.35	-1.01	-0.37
GXCOW with Household Income				
SUR Models				
Coefficient	-0.29	0.11	0.08	0.03
s.e.	0.19	0.04	0.18	0.04
t-statistic	-1.54	3.03	0.46	0.81
REM Models				
Coefficient	-0.08	0.08	0.10	0.06
s.e.	0.16	0.05	0.18	0.07
t-statistic	-0.49	1.65	0.57	0.84

Appendix Table 1. Summary of Selected Studies on Animal Source Foods Consumption and Child Growth

Authors, Year	Location	Methods[1]	Results and Comments
Walker et al. (1990)	Kingston, Jamaica	Anthropometric measurements, 24-hour food intake recall for N=129 stunted children and N=62 non-stunted children 9 to 24 months Comparison of mean dietary patterns and estimated energy and protein intake for the two groups	• Non-stunted children consumed a significantly higher number of dairy products (i.e., not amount consumed) • Estimated energy and protein intakes did not differ for the two groups • Differences in growth may be due to specific (micro) nutrient deficiencies and child morbidity. • Study does not control for other factors influencing growth
Seireg et al. (1992)	Managua, Nicaragua	Anthropometric measurements, 24-hour milk consumption recall for N=684 children 0 to 60 months Proportions of children stunted by whether child consumed breastmilk only, breastmilk and cow's milk, cow's milk only, or no milk Analysis of covariance with age and age^2 as covariates	• Mean HAZ were statistically significantly lower for children consuming no milk than for four age groups • Proportion of children stunted lower for those who drank milk on previous day than those who did not • Study does not control for other factors influencing growth
Allen et al. (1992)	Solís Valley, Mexico	Anthropometric measurements, food intake recall, observation, weighing and food record for N=67 pre-school children Multiple regression models	• Mean animal energy intake had a statistically significant positive impact on attained weight and length at 30 months (also weight Z-score), but this effect was statistically significantly negative when an interaction variable with maternal weight was also included in the model • In models of animal energy intake and interaction with maternal weight, maternal weight must be greater than 50 kg for net positive impact of animal energy intake • Study does not control for other factors influencing growth; coefficients may be biased due to endogeneity and omitted variables; unclear which variables are controlled for in each model

Authors, Year	Location	Methods[1]	Results and Comments
Guldan et al. (1993)	Rural Sichuan Province, China	Anthropometric measurements, 24-hour food intake recall, food frequency and socio-demographic data for N=389 children 4 to 12 months Comparison of frequencies in nutritional terciles by various factors (_^{2} tests)	• Children 7-9 months old in the upper tercile of weight-for-age Z-score (WAZ) were more likely to have consumed liver or blood products more than one time per week (rather less than or equal to one time per week) • Differences for other age groups not found. • Study does not control for other factors influencing growth
Kassouf (1993)	Brazil	Anthropometric measurements and socio-economic data for N=3914 children 1 to 5 years in national household survey Household model framework used to specify reduced-form demand equations for child nutritional status and child nutrition production functions (i.e., accounted for endogeneity of variables in determination of child nutritional status)	• Consumption of milk (binary variable) increased height-for-age Z-score (HAZ) 0.38 standard deviation units when selected other factors controlled for • Effect is likely not due entirely to milk consumption per se, given that other dietary factors were not included in the estimation
Neumann and Harrison (1994)	Embu, Kenya	Anthropometric measurements, food intake, and socio-economic data collected for N=130 infants 0 to 6 months, N=120 toddlers 18 to 30 months Multiple regression models including a variety of variables	• Maternal intake of animal protein during pregnancy a “significant” predictor of child’s length at 6 months (value not reported) controlling for a number of other variables • Protein (animal?) intake by the child was a “significant predictor” of length at 18 months (value not reported) controlling for child’s sex, socio-economic score (SES), maternal height, paternal height, fat intake, parental literacy, and the number of children in the household less than 6 years • Protein (animal?) intake by the child was a “significant predictor” of length at 30 months (value not reported) controlling for length at 18 months, maternal fat intake, season, household size, maternal height and SES • Coefficients may be biased due to endogeneity and omitted variables; variable selection ad hoc

Authors, Year	Location	Methods[1]	Results and Comments
Marquis et al. (1997)	Lima, Peru	Anthropometric measurements of growth (length) for N=107 toddlers 12 to 15 months for which "reverse causality" (breastfeeding behavior due to poor growth) was not observed Number of complementary food and animal product categories from food frequency surveys Multiple regression models including a variety of variables	• Neither the frequency of complementary food nor animal products consumption (i.e., the "main effects" of the regression models) had a statistically significant impact on growth; interaction effects were statistically significant • For toddlers consuming a low number of complementary foods, consumption of a larger number of animal foods increased growth • For toddlers consuming a low number of animal products, more frequent breastfeeding increased growth • Models do not account for endogeneity, actual intake not measured
Global Livestock CRSP (2002)	Embu, Kenya	Controlled intervention feeding trial with four treatments (snack supplementation with meat, milk, oil or no snack) for 2 cohorts (N=555) of Standard I primary school children (5 to 14 years, not pre-school), anthropometric measures and other indicators of nutritional status Hierarchical random effects models (details not reported) for first cohort of children, analysis of covariance (multiple regression models) Research ongoing, so results will undoubtedly be updated	• No statistically significant increase in growth reported for meat or milk treatments (although vitamin B_{12} status statistically significantly higher) • Covariates include endogenous variables such as morbidity and treatment food intake • Unclear how total food intake for child (i.e., including household meals) was affected by participation in the feeding trial and how this was controlled for in the analyses

[1] Includes a brief summary of only methods related to the results reported in this table, not all methods reported in the document.

Appendix Table 2. Summary of Selected Studies on Dairy Animal Ownership and Child Growth

Authors, Year	Location	Methods[1]	Results and Comments
Hitchings (1982)	Highland Kenya (tea and coffee zones east of the Rift Valley)	Anthropometric measurements, cropping patterns and socio-economic data for N=59 (tea zone) and N=144 (coffee zone) children 1 to 4 years Stepwise multiple regression for land area devoted to various crops, number of cows and other cattle owned by breed group and household size	Tea zones: • Number of grade cows owned had a statistically significant positive effect on height-for-age as a percentage of the Harvard standard height (+1.71 percentage points per cow) • Number of grade cows owned had a statistically significant negative effect on weight-for-height as a percentage of the Harvard standard (-0.23 percentage points per cow) • Number of native cattle owned had a statistically significant positive effect on height-for-age (+1.68 percentage points per cow) and weight-for-height (+2.31 percentage points per cow) Coffee zones: • Number of native cows owned had a statistically significant positive effect on height-for-age relative to the Harvard standard (+0.92 percentage points) • No statistically significant effects attributed to grade cows or cattle General: • Coefficients may be biased due to endogeneity and omitted variables; variable selection somewhat ad hoc

Authors, Year	Location	Methods[1]	Results and Comments
Leegwater et al. (1991)	Kilifi District, Kenya	Anthropometric measures and socio-economic data from N=44 children in households participating in NDDP; N=39 children in households regularly purchasing milk from NDDP farmers; N=138 children in households from the general population, for all children in these households aged 6 to 59 months Comparison of group means and distributions by household category	• Mean height-for-age as a percentage of the WHO standard was higher for NDDP farmer and NDDP customer households than for the general population • No statistically significant differences in mean weight-for-height as a percentage of WHO standard for the three types of households • For households with income 1,500-3,999 KSh/consumer unit, mean weight-for-height as a percentage of WHO standard was higher for the combined group of NDDP farmer and customer households • Effects cannot be attributed entirely to income, cattle ownership or milk consumption due to other differences not controlled for
Leonard et al. (1994)	Coastal Ecuador	Anthropometric measures and socio-economic data from N=43 children 0 to 6 years Stepwise multiple regression (variables with p>0.10 included)	• Combined number of cows, pigs, and chickens owned by the household had a statistically significant effect on HAZ (+0.24) in a model including child's age, per capita household food expenditures, and an intercept term • No allowance made for impacts of different animals; small sample size; coefficients may be biased due to endogeneity and omitted variables; variable selection ad hoc
Vella et al. (1995)	Mbarara District, Uganda	Anthropometric measurements, morbidity data and socio-economic data from N=4320 children 0 to 59 months Multiple regression	• Ownership of cows (binary variable) had a statistically significant impact on HAZ (+0.298 standard deviations) • Ownership of cows had no statistically significant effect on WHZ • Models include morbidity as an explanatory variable, so results may be affected due to endogeneity

Authors, Year	Location	Methods[1]	Results and Comments
Grosse (1998)	Rural Rwanda	Anthropometric data from 1992 for N=542 children 24 to 59 months, agro-economic data from 1990-91 crop years for the households involved Comparisons of livestock ownership groups and multiple regressions controlling for cluster (random) effects	• Children in households with cattle or goats had higher mean HAZ scores and a lower prevalence of severe stunting (not controlling for other factors) • A discrete dairy animal ownership index [0=no goats or cattle; 1=goats only; 2=cattle] had a statistically significant positive effect on HAZ (+0.287 standard deviations) in multiple regression models controlling for maternal height, maternal education, per capita income quartile, and housing characteristics • Coefficients may be biased due to endogeneity and omitted variables; variable selection ad hoc

[1] Includes a brief summary of only methods related to the results reported in this table, not all methods reported in the document.

Appendix Table 3. SUR Model Estimation Results for Cattle Ownership Status, by Region

Variable	WHZ Dependent				HAZ Dependent			
	Coast		Highlands		Coast		Highlands	
	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Constant	-1.35	0.52	1.36	0.66	-1.54	0.65	-3.55	1.00
Child Characteristics								
Birth order	0.15	0.04					-0.10	0.06
Sex (1=Male, 0=Female)			-0.27	0.11				
Age, months			-0.03	0.02			-0.05	0.02
Age squared			0.00	0.00			0.00	0.00
Household Head Characteristics								
Age, years			-0.07	0.03			0.10	0.04
Age squared			0.00	0.00			0.00	0.00
Sex (1=Male, 0=Female)					-1.27	0.40		
Education, years					0.07	0.02		
Religion dummy	0.42	0.26	0.18	0.12	0.34	0.25		
Ethnic group dummy	0.97	0.37	0.53	0.12			-0.20	0.18
Household Characteristics								
Land area owned, ha					-0.01	0.01		
Title deed? (1=Yes, 0=No)							0.36	0.18
Dependency ratio	-0.11	0.07			0.17	0.07	0.50	0.29
Milk price, KSh/liter					0.01	0.02		
Gift and remittance income, 000 KSh/mo			0.00	0.00				
District dummy (Kwale=1 or 1=Nakuru)	0.36	2.71			-0.28	0.37		
District dummy (Kilifi=1)	1.03	0.30	--	--	-0.80	0.32	--	--
Water dummy (1=Piped, 0=Other)	1.35	0.35	--	--	-0.69	0.37	--	--
Goats Owned? (1=Yes, 0=No)			--	--			--	--
Cattle Owned? (1=Yes, 0=No)	**-0.11**	**0.21**	**0.04**	**0.12**	**0.55**	**0.24**	**0.29**	**0.17**
Model Characteristics								
Adjusted R^2	0.15		0.16		0.16		0.07	
Log L	-203.63		-312.29		-422.05		-398.34	
Observations	139		245		139		245	

Appendix Table 4. REM Estimation Results for Cattle Ownership Status, by Region

Variable	WHZ Dependent				HAZ Dependent			
	Coast		Highlands		Coast		Highlands	
	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Constant	-2.22	2.23	0.97	0.85	-4.45	2.53	-3.74	1.20
Child Characteristics								
Birth order	0.13	0.04	-0.05	0.05	-0.05	0.05	-0.12	0.07
Sex (1=Male, 0=Female)	-0.17	0.16	-0.29	0.11	0.14	0.19	-0.27	0.16
Age, months	0.02	0.02	-0.03	0.02	0.02	0.02	-0.04	0.02
Age squared	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Household Head Characteristics								
Age, years	0.06	0.08	-0.06	0.03	0.07	0.09	0.10	0.05
Age squared	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sex (1=Male, 0=Female)	0.31	0.55	0.09	0.20	-1.18	0.59	-0.15	0.28
Education, years	-0.01	0.04	0.02	0.08	0.09	0.04	0.01	0.11
Religion dummy	0.34	0.40	0.18	0.14	0.27	0.44	0.10	0.20
Ethnic group dummy	0.92	0.53	0.40	0.18	0.00	0.61	-0.18	0.26
Household Characteristics								
Land area owned, ha	0.01	0.02	-0.01	0.01	-0.02	0.02	0.00	0.02
Title deed? (1=Yes, 0=No)	-0.43	0.43	-0.04	0.15	-0.26	0.45	0.36	0.21
Dependency ratio	-0.12	0.08	0.13	0.23	0.15	0.09	0.55	0.33
Milk price, KSh/liter	-0.03	0.02	0.00	0.01	0.04	0.02	0.01	0.02
Gift and remittance income, 000 KSh/mo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
District dummy (Kwale=1 or 1=Nakuru)	0.76	0.54	-0.05	0.25	-0.86	0.58	0.06	0.36
District dummy (Kilifi=1 for Coast)	0.52	0.47	--	--	-1.44	0.50	--	--
Water dummy (1=Piped, 0=Other)	1.28	0.54	--	--	-0.88	0.56	--	--
Goats Owned? (1=Yes, 0=No)	-0.03	0.32	--	--	-0.22	0.34	--	--
Cattle Owned? (1=Yes, 0=No)	**-0.13**	**0.37**	**0.03**	**0.15**	**0.85**	**0.40**	**0.36**	**0.21**
Model Characteristics								
Adjusted R2	0.23		0.21		0.24		0.21	
LM Test for Random Effects	11.83		1.99		9.61		2.37	
Observations	136		245		136		245	

Appendix Table 5. SUR Model Estimation Results for Dairy Cows Owned, by Region

Variable	WHZ Dependent				HAZ Dependent			
	Coast		Highlands		Coast		Highlands	
	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Constant	-2.39		1.29	0.67	-1.63	0.66	-3.88	1.01
Child Characteristics								
Birth order	0.16	0.04					-0.07	0.06
Sex (1=Male, 0=Female)	-0.12	0.18	-0.28	0.11			-0.18	0.16
Age, months			-0.03	0.02			-0.05	0.02
Age squared			0.00	0.00			0.00	0.00
Household Head Characteristics								
Age, years	0.05	0.05	-0.07	0.03			0.11	0.04
Age squared	0.00	0.00	0.00	0.00			0.00	0.00
Religion dummy	0.47	0.27	0.18	0.12	0.57	0.26		
Sex (1=Male, 0=Female)					-1.16	0.39	-0.21	0.24
Ethnic group dummy	0.94	0.38	0.54	0.12				
Education, years					0.08	0.02		
Household Characteristics								
Land area owned, ha					-0.01	0.01		
Title deed? (1=Yes, 0=No)							0.29	0.17
Dependency ratio	-0.13	0.07			0.12	0.07	0.63	0.30
Milk price, KSh/liter	-0.02	0.01			0.01	0.02		
Gift and remittance income, 000 KSh/mo			0.00	0.00	0.00	0.00	0.00	0.00
District dummy (1=Kwale or 1=Nakuru)	0.92	0.38			-0.36	0.38		
District dummy (1=Kilifi)	0.99	0.32			-0.77	0.34		
Water Dummy (1=Piped, 0=Other)	1.40	0.36			-0.44	0.37		
Total local cattle owned	-0.03	0.03			-0.01	0.03		
Number of dairy cows	**-0.05**	**0.10**	**0.01**	**0.02**	**0.26**	**0.11**	**0.03**	**0.02**
Model Characteristics								
Adjusted R^2	0.14		0.16		0.18		0.06	
Log L	-194.99		-310.98		-203.34		-396.13	
Observations	136		244		136		244	

Appendix Table 6. REM Estimation Results for Dairy Cows Owned, by Region

Variable	WHZ Dependent				HAZ Dependent			
	Coast		Highlands		Coast		Highlands	
	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Constant	-2.38	2.22	0.91	0.85	-3.47	2.54	-3.91	1.22
Child Characteristics								
Birth order	0.13	0.04	-0.04	0.05	-0.06	0.05	-0.11	0.08
Sex (1=Male, 0=Female)	-0.17	0.15	-0.30	0.11	0.14	0.19	-0.28	0.16
Age, months	0.02	0.02	-0.03	0.02	0.02	0.02	-0.04	0.02
Age squared	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Household Head Characteristics								
Age, years	0.07	0.08	-0.06	0.03	0.04	0.09	0.10	0.05
Age squared	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sex (1=Male, 0=Female)	0.32	0.55	0.09	0.20	-1.13	0.60	-0.15	0.29
Education, years	0.00	0.04	0.02	0.08	0.09	0.04	0.03	0.11
Religion dummy	0.35	0.40	0.19	0.14	0.21	0.45	0.13	0.20
Ethnic dummy	0.95	0.53	0.46	0.19	-0.06	0.62	-0.13	0.27
Household Characteristics								
Land area owned, ha	0.01	0.02	-0.01	0.01	-0.02	0.02	0.00	0.02
Title deed? (1=Yes, 0=No)	-0.39	0.41	-0.05	0.15	-0.14	0.45	0.37	0.22
Dependency ratio	-0.12	0.08	0.12	0.23	0.16	0.09	0.61	0.33
Milk price, KSh/liter	-0.03	0.02	0.00	0.01	0.03	0.02	0.00	0.02
Gift and remittance Income, 000 KSh/mo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
District dummy (1=Kwale or 1=Nakuru)	0.71	0.55	0.03	0.26	-0.98	0.59	0.12	0.38
District dummy (1=Kilifi)	0.49	0.48	--	--	-1.59	0.49	--	--
Water dummy (1=Piped, 0=Other)	1.20	0.51	--	--	-0.82	0.54	--	--
Total local cattle owned	-0.08	0.16	-0.02	0.04	0.10	0.18	0.00	0.05
Number of dairy cows	**-0.02**	**0.04**	**0.02**	**0.02**	**0.07**	**0.04**	**0.04**	**0.03**
Model Characteristics								
Adjusted R^2	0.24		0.2105		0.34		0.12	
LM test for random effects	9.61		2.37		9.95		7.78	
Observations	136		245		148		245	

Appendix Table 7. SUR Model Estimation Results for Dairy Cows Owned and Household Cash Income, by Region

Variable	WHZ Dependent				HAZ Dependent			
	Coast		Highlands		Coast		Highlands	
	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Constant	-3.64	1.61	1.55	0.66	-3.04	0.89	-3.88	1.02
Child Characteristics								
Birth order	0.13	0.04			-0.08	0.04	-0.08	0.06
Sex (1=Male, 0=Female)	-0.22	0.19	-0.27	0.11				
Age, months			-0.03	0.02			-0.05	0.03
Age squared			0.00	0.00			0.00	0.00
Household Head Characteristics								
Age, years	0.08	0.05	-0.09	0.03	0.02	0.01	0.10	0.04
Age squared	0.00	0.00	0.00	0.00			0.00	0.00
Religion dummy	0.44	0.27	0.26	0.12	0.58	0.25		
Sex (1=Male, 0=Female)	0.45	0.40	0.24	0.16	-0.80	0.41		
Ethnic group dummy	0.90	0.38	0.58	0.11				
Education, years			0.19	0.09	0.11	0.03		
Household Characteristics								
Land area owned, ha					-0.02	0.01		
Title deed? (1=Yes, 0=No)							0.31	0.17
Dependency ratio	-0.10	0.07			0.17	0.07	0.56	0.30
Milk price, KSh/liter	-0.02	0.01			0.02	0.02		
Gift and remittance income, 000 KSh/mo								
District dummy (1=Kwale or 1=Nakuru)	0.75	0.39			-0.57	0.39		
District dummy (1=Kilifi)	0.88	0.33			-0.99	0.34		
Water Dummy (1=Piped, 0=Other)	1.28	0.37			-0.67	0.38		
Total local cattle owned	-0.03	0.03			-0.01	0.03		
Number of dairy cows	**-0.29**	**0.19**	**0.11**	**0.04**	**0.08**	**0.18**	**0.03**	**0.04**
Predicted Household Cash Income, 000 KSh/mo	**0.05**	**0.04**	**-0.10**	**0.03**	**0.04**	**0.04**	**0.00**	**0.03**
Model Characteristics								
Adjusted R^2	0.14		0.18		0.22		0.06	
Log L	-189.82		-306.02		-194.68		-398.12	
Observations	134		244		134		244	

Appendix Table 8. REM Estimation Results for Dairy Cows Owned and Household Cash Income, by Region

Variable	WHZ Dependent				HAZ Dependent			
	Coast		Highlands		Coast		Highlands	
	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Constant	-2.20	2.26	1.09	0.86	-3.90	2.58	-3.84	1.23
Child Characteristics								
Birth order	0.13	0.04	-0.05	0.05	-0.06	0.05	-0.11	0.08
Sex (1=Male, 0=Female)	-0.17	0.14	-0.29	0.10	0.14	0.18	-0.27	0.16
Age, months	0.02	0.02	-0.03	0.01	0.01	0.02	-0.04	0.02
Age squared	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Household Head Characteristics								
Age, years	0.06	0.08	-0.06	0.03	0.06	0.09	0.10	0.05
Age squared	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sex (1=Male, 0=Female)	0.33	0.55	0.25	0.15	-1.15	0.60	0.16	0.21
Education, years	-0.01	0.04	0.11	0.20	0.10	0.04	-0.15	0.29
Religion dummy	0.34	0.41	0.51	0.20	0.20	0.45	-0.11	0.28
Ethnic dummy	0.96	0.53	0.14	0.12	-0.11	0.62	0.07	0.17
Household Characteristics								
Land area owned, ha	0.01	0.02	0.00	0.02	-0.02	0.02	0.00	0.02
Title deed? (1=Yes, 0=No)	-0.43	0.42	-0.09	0.15	-0.06	0.46	0.36	0.22
Dependency ratio	-0.12	0.08	0.02	0.24	0.15	0.09	0.57	0.34
Milk price, KSh/liter	-0.03	0.02	0.00	0.01	0.03	0.02	0.01	0.02
Gift and remittance Income, 000 KSh/mo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
District dummy (1=Kwale or 1=Nakuru)	0.70	0.55	0.02	0.27	-0.95	0.59	0.12	0.38
District dummy (1=Kilifi)	0.49	0.48	--	--	-1.63	0.49	--	--
Water dummy (1=Piped, 0=Other)	1.20	0.51	--	--	-0.84	0.54	--	--
Total local cattle owned	-0.02	0.04	-0.02	0.04	0.07	0.04	0.00	0.05
Number of dairy cows	**-0.08**	**0.16**	**0.08**	**0.05**	**0.10**	**0.18**	**0.06**	**0.07**
Predicted Household Cash Income, 000 KSh/mo	**0.00**	**0.00**	**-0.07**	**0.05**	**0.00**	**0.00**	**-0.03**	**0.07**
Model Characteristics								
Adjusted R^2	0.25		0.23		0.33		0.12	
LM test for random effects	9.36		0.99		11.03		6.91	
Observations	136		245		148		245	

Figure 1. Conceptual Model of Impacts of Dairy Cow Ownership on Child Nutrition