Adoption of Crossbred Cow Technologies and Increased Food Security Among Smallholder Dairy Farmers in the East African Highlands

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SUMMARY. This study investigates the household-level impacts of market-oriented dairy technologies (crossbred cows and complementary feed and management technologies) on incomes, food and non-food expenditures, nutrient intakes, and health of pre-school children. A recursive econometric model was employed using detailed household level survey data of production, income and consumption, nutrition, and health. Results show that market-oriented technologies are significant determinants of income. The size of the cultivated area, herd size, and purchased inputs are positively and strongly associated with the level of per capita income. Predicted income has a positive and significant influence on expenditures of food and non-food items. Price of food, however, has a negative and significant impact on expenditures. Results also indicate that women’s knowledge, expenditure on food, and price of nu-
trients are important determinants of nutrient intakes. The analysis of the factors affecting the health status revealed that women’s practice and knowledge, and age of the mother and female headship are important determinants of the weight-for-age and weight for height scores. Also, participation in village-level health programs has a significant effect (at 10% level) on the weight for height. The policy implications resulting from this study clearly indicate that strategies that promote market-oriented smallholder dairy can improve food security as it contributes to an increased per capita income, thereby increasing per capita expenditure on food and non-food items. This increase in turn, positively affects the intake of nutrients. Therefore, to improve health, it is useful to focus on the role of woman in the household.

KEYWORDS. Dairy technology, food expenditures, food security income, nutrition

INTRODUCTION

Improving human nutrition, including their micronutrient status, is a critical element for achieving food security in East African Highlands. In contrast to the developed world where a lot of people eat too many animal products, most people throughout sub-Saharan Africa eat too few animal products for good nutrition. Thus, interest is mounting for food-based approaches (dietary change) to combat nutrient and micronutrient deficiencies (Ehui et al., 1998). Increased consumption of livestock and dairy products can make a unique and critical contribution to human nutrition because low levels of animal and fish consumption among the poor and the relatively high bioavailability of minerals and vitamins contained in animal products. Neumann, Bwibo, and Sigman (1993) have shown that consumption of animal products increases the bioavailability of minerals and vitamins in plant foods consumed at the same meal.

Animal products, especially dairy, also contribute to improving food security because they are a critical source of income for many smallholders in the East African Highlands. For many countries in the region, dairy production is the most important income generator (Ehui et al., 1998, p. 83). The introduction of market-oriented dairy technologies (e.g., crossbred cows and complementary feed and management technologies) can result in increased commercialization of dairy products by smallholder farmers when marketable surpluses
The increased income from sales of dairy products may also be spent on more and better quality food and result in improved nutrition and health. Consumption of more dairy products usually results in a positive effect on human nutrition and health (Neumann, Bwibo, and Sigman, 1993).

The objective of this paper is to determine the linkages between adoption of market-oriented dairy technologies, and household income, expenditures on food and non-food, and improved human nutrition as measured by calorie, protein, carotene, and iron intake, and preschooler’s health indicators in Ethiopia. The above relationships are estimated using econometric recursive models to identify the determinants of these linkages. The dairy technologies being assessed are the results of a long-term research program between the International Livestock Research Institute (ILRI) and the Ethiopian Research Organization (EARO) that aimed at increasing milk and meat production, household income, use of dairy cows for traction, and nutritional status of household members.

The results of this study are particularly relevant for nutrition and food security policies in the East African region in general, and Ethiopia in particular, where there are several on-going programs to combat malnutrition. Examples of programs in Ethiopia include: community school and health-based nutrition education; regular provision of micronutrients to high risk (targeted) groups through supplementation programs; and ensured access at the household level to an adequate supply of nutrition through promotion of horticulture and livestock activities.

The paper is organized as follows: The next section expounds the theoretical household model; Section 3 outlines the empirical data used in estimation; The study area and the model are presented in section 4; The results are discussed in section 4 and the paper concludes in section 5.

**THEORETICAL FRAMEWORK OF THE HOUSEHOLD MODEL**

The farm household maximizes a utility function of the form:

$$U = U(X_a, X_m, X_l)$$  \hspace{1cm} (1)

Subject to a cash income constraint:

$$p_m X_m = p_a (Q - X_a) - w (L - F)$$  \hspace{1cm} (2)

Where $X_a$, $X_m$, and $X_l$ are agricultural commodity (staple), a market purchased good and leisure, respectively. $p_m$ and $p_a$ are the prices of the market-purchased commodity and the staple, respectively, $Q$ is the household’s produc-
tion of the staple, \( w \) is the market wage, \( L \) is total labor input, and \( F \) is family labor input. The quantity \( Q - X_a \) is the household’s marketed surplus, if positive. If \( (L - F) \) is positive, the household hires labor, if it is negative, there is off-farm labor supply from the household.

A household also faces a time constraint:

\[
X_l + F = T
\]  
(3)

Where, \( T \) is the total stock of household time. The other constraint the farm household faces is related to production technology that depicts the relation between inputs and outputs.

\[
Q = Q(L, A)
\]  
(4)

Where, \( A \) is the household’s fixed quantity of land.

The underlying assumptions for the above formulations are:

- In spite of the relevance of capital inputs such as fertilizer, pesticide, etc., they are not included in this illustration;
- The possibility that more than one crop can be produced is not included;
- Family labor and hired labor are perfect substitutes; and
- The three prices, namely \( p_m, p_a, \) and \( w \) are not affected by actions of the household, (i.e., the household is a price-taker in the three markets). This last assumption, if it holds, guarantees a recursive model.

Then, the three constraints (i.e., Equations 2, 3, and 4) can be combined as follows:

Substituting Equation 4 into Equation 2 for \( Q \) and the time constraint into the cash income constraint for \( F \), yields a single constraint:

\[
p_m X_m = p_a [Q(L, A) - X_a] - w(L - F)
\]  
(5)

Since \( F = T - X_l \), Equation 5 becomes,

\[
p_m X_m = p_a [Q(L, A) - X_a] - w(L - T + X_l)
\]  
(6)

Rearranging Equation 6 yields,

\[
p_m X_m + p_a X_a + wX_l = p_a Q(L, A) - w(L - T)
\]  
(7)
Further rearrangement of Equation 7 gives,

\[ p_m X_m + p_a X_a + w X_l = wT + p_a Q(L, A) - wL \]  

(8)

Finally from Equation 8, we get

\[ p_m X_m + p_a X_a + w X_l = wT + \pi \]  

(9)

Where \( \pi = p_a Q(L, A) - wL \) is a measure of farm profits. The left-hand side of Equation (9) represents the household’s total expenditure on three items: market-purchased commodity, household’s purchase of its own output, and household’s purchase of its own time in the form of leisure. The right-hand side of the equation is the farm household’s full income in which the value of the stock of time \((wT)\) owned by the household is explicitly recorded.

In these equations, the household can choose the level of consumption for the three commodities and total labor input into agricultural production. The first order conditions for maximizing each of labor is:

\[ \frac{p_a \partial Q}{\partial L} = w \]  

(10)

The household will equate the marginal revenue product of labor to the market wage. Since the other endogenous variables do not appear, and therefore, do not influence the household’s choice of \(L\), production decisions can be made independently of consumption and labor-supply (or leisure) decisions. Let the solution for \(L\) be

\[ L^* = L^*(W, p_a, A) \]  

(11)

This solution can then be substituted into the right-hand side of the constraint to obtain the value of full income when farm profits have been maximized through an appropriate choice of labor input. The full income constraint can be rewritten as,

\[ Y^* = p_m X_m + p_a X_a + w X_l \]  

(12)

Where \(Y^*\) is the value of full income associated with profit-maximizing behavior. Maximizing utility subject to this new version of the constraint yields the following first-order conditions:

The Lagrangian multipliers method for solving the above constrained optimization problem can be formulated as:

\[ L(X_a, X_m, X_l, \lambda) = U(X_a, X_m, X_l) + \lambda (Y^* - p_m X_m - p_a X_a - wX_l) \]  

(13)
The first order conditions for maximization are:

\[ \frac{\partial L}{\partial X_a} = \frac{\partial U}{\partial X_a} - \lambda p_a = 0 \]

\[ \frac{\partial L}{\partial X_m} = \frac{\partial U}{\partial X_m} - \lambda p_m = 0 \]

\[ \frac{\partial L}{\partial X_l} = \frac{\partial U}{\partial X_l} - \lambda w = 0 \]  \hspace{1cm} (14a)

\[ \frac{\partial L}{\partial \lambda} = Y^* - p_m X_m - p_a X_a - w X_l = 0 \]

From Equation 14a we get,

\[ \frac{\partial U}{\partial X_a} = \lambda p_a \]

\[ \frac{\partial U}{\partial X_m} = \lambda p_m \]  \hspace{1cm} (14b)

\[ \frac{\partial U}{\partial X_l} = \lambda w \]

\[ p_m X_m + p_a X_a + w X_l = Y^* \]

Equation 14b holds the standard conditions from consumer-demand theory. For \( i = m, a, l \), the solution of Equation 13 yields standard demand curves of the form:

\[ X_i = X_i(p_m, p_a, w, Y^*) \]  \hspace{1cm} (15)

Equation 15 shows that demand depends on prices and income, where in the case of farm households, income is determined by the household’s production activities. It therefore follows that changes in factors influencing production will also change \( Y^* \), and hence, consumption behavior.

The nutrient intake including calorie, protein, iron and \( \beta \)-carotene can be derived directly from the demand equation for food in Equation 15 and can be represented as:
\[ C = C(p_a, p_m, w, Y, Z) \]  
(16)

Where the arguments are as defined above and \( Z \) is a vector of other household characteristics.

**EMPIRICAL SPECIFICATION OF THE RECURSIVE MODEL**

Based on the above description, the following issues are addressed recursively in assessing the impact of market-oriented dairy technologies:

- The impact of the dairy innovation on household incomes.
- The impact of incremental increases in income on food expenditure, and non-food expenditure.
- The impact of incremental increases in food expenditure on calorie, protein, iron, and carotene intake indicating better access to food and improved nutrition.
- The impact of incremental increases in nutrient intake on health indicators of preschoolers.

These issues and outcomes are modeled as part of the farm household’s utility function, following Bouis and Haddad (1990) and Kumar (1994). The empirical recursive econometric model consists of income, expenditure, nutrients, and health relations. The explanatory variables can, generally, be disaggregated into resources such as labor, land, livestock holding size and composition, capital inputs and socio-economic variables describing household and farm characteristics that influence income, expenditure, and consumption decisions. Household socio-economic characteristics include family size, age, education, and sex of the household head, dependency ratio, ratio of women in the household and mothers’ knowledge, attitude, and performance. Among farm characteristics are its proximity to the market. The following system of recursive equations is used in the empirical estimation.

1. Income equation:

\[ Y = f(LAND, INPUT, TRACT, FLBOR, NFLBOR, LIVES, STRAW, GROUP, EDUC, AGE, SEX, DRATIO, FRATIO, MKT) \]  
(17)

2. Seasonal expenditure equations:

\[ EXP_j = f(Y, PRICE, MKT, OFFSH, FS, DRATIO, FRATIO, AGE, SEX, EDUC, d_t) \]  
(18)

where \( j = \text{food (f)} \) or non-food (nf)
3. Seasonal nutrient intake equations:

\[ C_i = f(\text{EXP}_f, \text{NVPRICE}_i, \text{KAP}, \text{CEREAL}, \text{PULSES}, \text{DRATIO}, \text{FRATIO}, \text{FS}, \text{EDU}, \text{SEX}, \text{AGE}, \text{AGEM}, \text{EDUM}, d_i) \]  

(19)

where \( i = \text{protein (p)}, \text{calorie (cal)}, \text{iron (ir)} \) or \( \beta\text{-carotene (car)} \)

4. Health indicator equations:

\[ \text{WAZ} = f(C_i, \text{KAP}, \text{SEXC}, \text{EDUM}, \text{AGEM}, \text{PRVILH}, \text{KNBAL}, \text{PRVAC}) \]

(20)

where:

- \( Y \) is the per capita income, which includes sales of farm products and off-farm income (Birr¹);
- \( \text{EXP}_f \) and \( \text{EXP}_{nf} \) are per capita expenditure on food and non-food, respectively;
- \( C_i \) includes \( C_{\text{cal}}, C_{\text{p}}, C_{\text{ir}}, \) and \( C_{\text{car}} \) which are, respectively, per capita intake of calorie, protein, iron, and \( \beta\text{-carotene} \);
- \( \text{WAZ}, \text{WHZ}, \) and \( \text{HAZ} \) are, respectively, the weight for age, weight for height and height for age \( Z \)-scores of the indexed child in the household;
- \( \text{LAND} \) is the area of land cultivated by the household (ha);
- \( \text{INPUT} \) is the value of purchased inputs including seed, fertilizer and other chemicals (Birr);
- \( \text{TRACT} \) is number of hours of animal traction applied to crop production (hrs);
- \( \text{FLBOR} \) is the number of family labor hours used in crop and livestock (hrs);
- \( \text{NFLBOR} \) is the number of non-family labor hours used in crop and livestock (hrs);
- \( \text{STRAW} \) is amount of straw produced during 1996 cropping year;
- \( \text{LIVES} \) is the livestock herd size expressed as tropical livestock units (TLU);
- \( \text{PRICE} \) is unit price of food;
- \( \text{NVPRICE} \) is the weighted average price per unit of nutrient (Birr);
- \( \text{CEREAL} \) is the area allocated to cereal (ha);
- \( \text{PULSES} \) is the area allocated to pulses (ha);
- \( \text{GROUP} \) is a dummy variable indicating if the household owns (CBC = 1 and 0 otherwise);
- \( \text{EDUC} \) is the highest education attained by the head of the household,
- \( \text{AGE} \) is the age of the head of the household (years);
- \( \text{EDUCM} \) is the highest education attained by the mother;
- \( \text{AGEM} \) is the age of the mother (years);
• SEX is the sex of the head of the household (male = 0; female = 1);
• SEXC is the sex of the indexed child (male = 0; female = 1);
• FS is the family size expressed in adult equivalent;
• DRATIO is the dependency ratio defined as the number of dependents to number of independent adults;
• FRATIO is the ratio of women in the household;
• MKT is the distance to the nearest market expressed in walking time to and from the market center;
• OFFSH is the share of off-farm employment in total income of the household;
• KAP is an index measuring mother’s knowledge, attitude and practice;
• KNBAL is knowledge, specifically, of balanced diet (yes = 1; 0 otherwise);
• PRVILH is participation in village health program (yes = 1; 0 otherwise);
• PRVAC is participation in vaccination during pregnancy (yes = 1; 0 otherwise); and
• \( d_t \) is seasonal dummy variables.

Expenditure on food does not include the value of food produced on the farm, but only for that which is purchased. However, calorie intakes do include food from all sources, purchased and non-purchased. Because of the likelihood of the simultaneity problem, variables on the right hand side of each individual equation may be tested for simultaneity using Hausman’s test (Hausman, 1978) at each stage in the system. If the test rejects the null hypothesis of no simultaneity, an instrumental variable technique is used. Also, multicollinearity may be detected using variance inflation factor (VIF) test. VIF is the diagonal element of the inverse of correlation matrix, which is \((1-R^2_i)^{-1}\), where \(R^2_i\) is the \(R^2\) obtained from regressing the \(i^{th}\) independent variable on all other independent variables (Kennedy, 1985:153). Therefore, a high VIF indicates an \(R^2_i\) near unity and hence suggests collinearity. According to Kennedy (1985), VIF of more than 10 indicates a harmful collinearity. This approach was used to exclude collinearity problems in the estimation process. The expenditure equations and nutrient intake equations were estimated each as a system using seemingly unrelated regression while the income equation and health indicator equations are estimated as single equations using OLS.

**STUDY AREA AND SOURCES OF DATA**

The study site is located in the Ethiopian highlands, about 40 km west of Addis Ababa in the vicinity of a small town called Holetta. The altitude of the
research area is about 2600 meters above sea level. The average annual rainfall is 1100 mm with mean daily temperature of less than 20 degree centigrade. The main rainy period, known as the Meher season, starts in mid-June and continues up to September. The short rains or Belg are from February to April and are mainly used to break the soil. Farmers in Holetta depend on the Meher rains to plant crops. The farming system in the study area is classified as a mixed crop-livestock system with livestock playing an important role for provision of food (milk and meat), draft power, and dung, which is used for soil fertility enhancement as well as fuel.

The Holetta area is characterized by variable soils with a predominance of red brown soils, low water holding capacity on the slopes, and poorly drained heavy dark clay soils (vertisols) mostly in the valleys. Three types of soils can be identified on farm plots: vertisols, light and mixed upland soils, and heavy upland soils with vertisol properties. Farmers produce a wide range of cereal and legume crops on small parcels of land. The production is geared towards satisfying the household food requirements as well as a provision for feeding livestock in the form of straw and hay. The major crops are barley in the belg season, and wheat, teff, oats, and horse beans in the mehr season. Other minor crops include field peas, chickpeas, linseed, sorghum, and rapeseed. Farmers usually use manure, urea, and diammonium phosphate for soil fertility management. These inputs are either used individually or in combination, depending on availability, type of soil of the plot, and crops grown.

Beside crops, the household keeps a herd of animals, mainly consisting of dairy cows, at least two oxen for ploughing, heifers, bulls, goats, sheep, and chicken. Because of the dependency on animal traction for crop production, keeping at least a pair of oxen and a follower herd (heifers and bulls) for replacement is necessary despite the feed shortage. To ease the feed shortage, dairy-draft crossbred cows (CBC) and adoptions of on-farm forage production are encouraged. This technology allows the farmer to reduce the herd size while maintaining the capacity for both animal traction and milk production. However, farmers are reluctant to use crossbred cows for traction.

Holetta is one of the areas where crossbred cows were introduced to increase dairy production to meet the increasing demand of the neighboring urban areas and to improve farmers’ incomes and nutrition. The area is considered to have a high dairy potential due to its adequate agro-ecological conditions and market access to Addis Ababa. Farm households are organized into peasant associations through which they are allocated usufruct rights to farmland. Individual farm households on small plots averaging about 1.5 hectares carry out crop production. They also have grazing areas of about 0.5-1.0 hectares. Because of the high population pressure and small farm sizes, intensification through the introduction of new technology is a distinct possibility. However, the practice of growing fodder crops for animals is rare, and there is an acute
shortage of high quality feed, necessary for maintaining crossbred cows. Some of the newly introduced feeds intended to alleviate this problem include fodder beet, oat-vetch inter crop, and leguminous trees.

The data used for this study was generated by a collaborative dairy technology project involving the Ethiopian Agricultural Research Organization (EARO), and the International Livestock Research Institute (ILRI). One major objective of the project was to develop technologies to enable resource poor smallholder mixed crop-livestock farmers to participate in market-oriented dairying. Another objective was testing the use of crossbred dairy cows for traction, as well as milk production.

Pairs of crossbred dairy cows were introduced on 14 farms in Holetta in 1993, half for only milk production, and half for traction, as well as milk production. On-farm mean milk yield and average lactation days were not as such affected by traction, given adequate feeding (Stall, Steven, and Shapiro, 1994). Thus, the use of the crossbred cows for traction by households, in addition to dairy production, is not considered of relevance for the purposes of this study.

During 1995 and early 1996, 120 more crossbred cows were introduced into the community and an additional 60 households could use the cows for traction, in addition to milk production and reproduction. Another 60 control households using traditional practices of local Zebu cows for milk production and oxen for traction have been monitored starting mid-1996. In total, 134 households were surveyed for one year from October 1996 through September 1997. This enabled comparison of the income and nutritional status of the two groups of households, namely 65 households with crossbred cows (CBC participants) and 60 without crossbred cows (non-participants).

Data collection included land use, labor allocation to different operations, draught power use and source, input use, output disposal, income, expenditure, and price data. Food availability and food intake by household member were also collected. In addition, data on demographic, resources endowment, cropping and livestock activities were carried out. Food intake of 84 farm households was monitored for one day per month from March to December 1997. Special attention was given to the nutrition and health effects on children and women since they are the most vulnerable social group to food insecurity. The target population of the study thus included all members of households with preschool children of 6 months to 6 years. The nutritional records included both the CBC participants and non-participants.

The Ethiopian Health and Nutrition Research Institute (EHNRI) measured anthropometric indicators (weight for height, weight for age and height for age) on preschool children in all the households. Anthropometric measurements were focused on preschool children of 6 months to 6 years since they have relatively high risks of being affected by nutrient-deficiency resulting in health problems. Furthermore, due to their key positions in ensuring food
availability for all household members, child health care measures and the nutritional knowledge of mothers were assessed. Environmental health factors, childcare and health care measures, child morbidity, and mothers’ nutritional knowledge were also covered.

**RESULTS**

In the recursive analysis, the determinants of per capita income were estimated using the variables shown in Equation (17). Then the expenditure functions (Equation 18) were estimated after testing for simultaneity between the expenditure and income functions based on Hausman test (Hausman, 1978). The test rejected the hypothesis of no simultaneity between the two. Hence, the instrumental approach was used in the simultaneous estimation of the expenditure functions. A similar procedure was followed in the estimation of the parameters of the consumption functions, which were estimated simultaneously.

**Impacts on Income**

Test for multicollinearity among the independent variables was made using variance inflating factor (VIF). The higher the value of the VIF, the higher is the degree of multicollinearity, and hence, the lesser is the efficiency of parameter estimation. Usually, VIF of more than 10 is associated with a high degree of multicollinearity. Such a test was conducted for all variables in each of the models estimated.

A log-linear function was used to estimate the coefficients of the per capita income function determinants. Results are summarized in Table 1. As expected, adoption of the improved dairy cows significantly increases the per capita income of households. The results show that factor inputs such as land, and seeds and chemical fertilizer (INPUT), and straw production contribute significantly to per capita income. The signs of these variables are also as expected. As crop production is the most important source of household income, it is apparent that as the size of cultivated area increases, per capita income also increases. On the other hand, family size is found to have a negative impact on the level of per capita income. This impact is generally true when there is a high dependency ratio, which holds true also in the study area. Therefore, although a large family may provide a high reserve of labor for generating income, the children, elderly, and the disabled members of the household do not contribute to the income generation.

Family labor has a negative relationship with per capita income. But non-family labor is positively and significantly associated with per capita income. This relationship may be due to the fact that when a household earns
high income, it employs labor to operate on its farm and engages itself on other activities.

There are two unexpected signs in the estimated models: namely access to market and the level of education attained. The results further show that there is a negative relationship between the income level and the age of the head of the household. Although experience comes with age, it is possible that younger farmers are more able to acquire newer skills. The per capita income is negatively associated with female headship of the household. This result may be due to the poor resource basis of this group of farmers since the model depicted that the productive resources are important determinants of per capita income.

**Impacts on Food and Non-Food Expenditures**

Hausman (1978) provides a procedure to detect simultaneity between the predictor variable(s) and the dependent variable. Proceeding with the ordinary least squares (OLS) procedure without conducting this test would result in in-

### TABLE 1. Determinants of Income per Adult-Equivalent

<table>
<thead>
<tr>
<th></th>
<th>β</th>
<th>t-value</th>
<th>Sig</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tolerance</td>
</tr>
<tr>
<td>Constant term</td>
<td>3.4544</td>
<td>6.42</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>Cultivated area¹</td>
<td>0.1952</td>
<td>4.03</td>
<td>0.0001</td>
<td>0.5339</td>
</tr>
<tr>
<td>Input (seed, fertilizer, chemicals)¹</td>
<td>0.0898</td>
<td>1.71</td>
<td>0.0891</td>
<td>0.2413</td>
</tr>
<tr>
<td>Age of head of HH²</td>
<td>−0.3490</td>
<td>−4.54</td>
<td>0.0000</td>
<td>0.4782</td>
</tr>
<tr>
<td>Straw produced in 1996¹</td>
<td>0.3623</td>
<td>5.47</td>
<td>0.0000</td>
<td>0.1738</td>
</tr>
<tr>
<td>Female ratio</td>
<td>0.0009</td>
<td>0.73</td>
<td>0.4652</td>
<td>0.7227</td>
</tr>
<tr>
<td>Education of head (highest attained)</td>
<td>−0.0408</td>
<td>−1.62</td>
<td>0.1063</td>
<td>0.4789</td>
</tr>
<tr>
<td>Sex of head (Male = 1, Female = 2)</td>
<td>−0.2888</td>
<td>−3.27</td>
<td>0.0012</td>
<td>0.8525</td>
</tr>
<tr>
<td>Traction hrs</td>
<td>0.0001</td>
<td>0.76</td>
<td>0.4462</td>
<td>0.7470</td>
</tr>
<tr>
<td>TLU per adult-equivalent</td>
<td>0.0111</td>
<td>0.32</td>
<td>0.7511</td>
<td>0.4144</td>
</tr>
<tr>
<td>Family labor¹</td>
<td>−0.1276</td>
<td>−2.68</td>
<td>0.0079</td>
<td>0.3645</td>
</tr>
<tr>
<td>Non-family labor¹</td>
<td>0.1314</td>
<td>4.22</td>
<td>0.0000</td>
<td>0.3733</td>
</tr>
<tr>
<td>Family size (adult-equivalent)</td>
<td>−0.0990</td>
<td>−8.26</td>
<td>0.0000</td>
<td>0.4252</td>
</tr>
<tr>
<td>Dependency ratio</td>
<td>−0.0001</td>
<td>−0.29</td>
<td>0.7726</td>
<td>0.6991</td>
</tr>
<tr>
<td>GROUP (CBC = 1, Non-CBC = 0)</td>
<td>0.2039</td>
<td>4.31</td>
<td>0.0000</td>
<td>0.6033</td>
</tr>
<tr>
<td>Round trip travel time to nearest market</td>
<td>0.0002</td>
<td>0.50</td>
<td>0.6143</td>
<td>0.8121</td>
</tr>
<tr>
<td>R square</td>
<td>0.70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted R square</td>
<td>0.68</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ Natural log of the variable is used in the model.

² Sex: Male = 1; Female = 2.

consistent estimates. Simultaneity implies that the predictor (explanatory) variable(s) will be endogenous, and therefore, correlate with the disturbance term.

For the determinants of food expenditure per capita, the relevant question is whether income (the predictor variable) is determined simultaneously with per capita expenditure (the dependent variable). The Hausman test is a two-step procedure. The first step involves OLS estimation of the income function by including all exogenous variables of the expenditure and the income functions (Bouis and Haddad, 1990; Pindyck and Rubinfeld, 1991).

The second step involves estimation of expenditure functions either on the predicted income or on the residuals of the income function estimated in step 1 and the other explanatory variables of the expenditure function. Finally, conducting a hypothesis test on the coefficient of either the predicted income or the residual term concludes the presence or absence of simultaneity (Bouis and Haddad, 1990; Pindyck and Rubinfeld, 1991). Following Pindyck and Rubinfeld (1991) the significance of the residual value in the step 2 of simultaneity test is used as an indicator of endogeneity.

Results of the test rejected the null hypothesis of no simultaneity indicating that simultaneity exists between the expenditure and income functions. Hence, the two expenditure functions shown in Equation (18) are simultaneously estimated using a three-stage OLS estimation procedure (White et al., 1990) with predicted income rather than observed income. The estimated parameters of the food and non-food expenditure functions are summarized in Table 2.

The result shows that (as expected) the instrumental variable explains the variation in the expenditure for non-food items rather than the expenditure on food. The result may be acceptable under the conditions of subsistence farmers who rely on their own food supply than on purchases of staples. However, with increased integration of improved dairy production and off-farm activities, the significance level of the influence may change. This result has also been evidenced by the fact that the share of off-farm income positively explains the expenditure on food.

As expected, the price of food has a negative and significant influence on the expenditure on food as well as non-food items. Moreover, the accessibility to markets has a negative and significant effect on expenditure. As hypothesized, the higher the proportion of female in the household, the more expenditure on food there will be. Moreover, the regression analysis shows that male-headed households tend to spend more showing perhaps the extent to which the male dominates the appropriation and disposal of the household income. The result is consistent with studies undertaken in Kenya (Kennedy, Peters, and Haddad, 1994).

Regarding the relationship between the ages of the heads of the household, the result shows that younger farmers tend to spend more on food and
non-food goods. Seasonality also plays a significant role in expenditure decisions. As the family size increases, the households tend to minimize the risk of food shortage by producing more of their subsistence requirement of their members. The result of the study proved this argument. The overall power of the models shows that about 56% of the variations in the expenditure for food is explained by the variables included in the model. The proportion is lower for the non-food expenditure model (40%).

### Impacts on Consumptions of Nutrients

Recursive estimation procedure was adopted to estimate the consumption equations. Prior to the estimation of the consumption equation, Hausman test was performed to check if there was simultaneity between the consumption function and the expenditure function. Similar testing procedure was followed as described under previous section. In the first step, the expenditure function was defined including all exogenous variables of the expenditure and the consumption functions. In addition to the variables included in Equation (18), all variables exogenous to the consumption functions were included in the regression. The explanatory variables in the four consumption models are the same

### TABLE 2. Determinants of Expenditure Functions

<table>
<thead>
<tr>
<th>Variables</th>
<th>Expenditure on Food</th>
<th>Expenditure on Non-Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted per capita income*</td>
<td>0.0710, 1.83c</td>
<td>0.0580, 3.04a</td>
</tr>
<tr>
<td>Price of food*</td>
<td>−0.5057, −7.94a</td>
<td>−0.1480, −1.06</td>
</tr>
<tr>
<td>Access to off-farm work (share of income)</td>
<td>0.002, 1.96b</td>
<td>0.0006, 0.24</td>
</tr>
<tr>
<td>Distance to nearest market*</td>
<td>−0.1585, −5.16a</td>
<td>−0.2521, −3.79a</td>
</tr>
<tr>
<td>Female ratio in the household</td>
<td>0.0063, 2.90a</td>
<td>0.0017, 0.36</td>
</tr>
<tr>
<td>Dependency ratio</td>
<td>0.00002, 0.03</td>
<td>−0.0013, −1.01</td>
</tr>
<tr>
<td>Family size</td>
<td>−0.0865, −6.47a</td>
<td>−0.0704, −2.52b</td>
</tr>
<tr>
<td>Age of head of household</td>
<td>−0.2682, −2.67a</td>
<td>−0.6369, −2.92a</td>
</tr>
<tr>
<td>Sex of head of household</td>
<td>−0.5516, −1.91c</td>
<td>−0.2471, −0.39</td>
</tr>
<tr>
<td>Education of head of household</td>
<td>0.0415, 1.45</td>
<td>−0.0129, −0.21</td>
</tr>
<tr>
<td>QUARTER1</td>
<td>0.2297, 3.58a</td>
<td>1.4411, 10.34a</td>
</tr>
<tr>
<td>QUARTER2</td>
<td>0.3872, 5.96a</td>
<td>1.1856, 8.41a</td>
</tr>
<tr>
<td>QUARTER3</td>
<td>0.3537, 5.54a</td>
<td>0.8695, 6.28a</td>
</tr>
<tr>
<td>Constant</td>
<td>4.7021, 8.33a</td>
<td>6.6796, 6.18a</td>
</tr>
<tr>
<td>R square</td>
<td>0.5594</td>
<td>0.4034</td>
</tr>
</tbody>
</table>

* Natural log of the variable is used.

a, b, and c = sig. at 1%, 5%, and 10% level, respectively.

except for the prices of nutrition that depend on the type of nutrition under consideration.

In the second step, the residual of the model estimated in Step 1 is used together with variables in Equation (19). The result shows that the coefficient of the residual value in all the consumption models are found to be insignificant showing that there is no statistical evidence to accept the null hypothesis that there is no simultaneity. Hence, equations for calorie, protein, iron, and carotene and expenditure were estimated using the three-stage least squares method for simultaneously estimating the four systems of consumption function. The results shown in Table 3 show that there is a very strong and negative relationship between the unit prices of the nutritive value and their consumption. On the other hand, there is a positive and strong relationship between nutrient intake and expenditure on food, except in the case of calorie intake due to the reasons indicated above (i.e., reliance on own production). There is an inverse, but significant relationship between the age of mothers and per capita nutrient intake. Furthermore, there is a positive association between female-headed household and nutrient intake. Knowledge, attitude, and practices are more

<table>
<thead>
<tr>
<th>Variables</th>
<th>Calorie</th>
<th>Protein</th>
<th>Iron</th>
<th>β-Carotene</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>t</td>
<td>β</td>
<td>t</td>
</tr>
<tr>
<td>Food expenditure</td>
<td>-0.0103</td>
<td>-0.41</td>
<td>0.0164</td>
<td>0.68</td>
</tr>
<tr>
<td>Nutrition value price</td>
<td>-0.2054</td>
<td>-15.42a</td>
<td>-0.4140</td>
<td>-20.25a</td>
</tr>
<tr>
<td>KAP</td>
<td>0.017</td>
<td>0.58</td>
<td>0.0693</td>
<td>2.49b</td>
</tr>
<tr>
<td>Family size</td>
<td>-0.0472</td>
<td>-6.62a</td>
<td>-0.0412</td>
<td>-6.05a</td>
</tr>
<tr>
<td>Education of head of HH</td>
<td>-0.0582</td>
<td>-3.74a</td>
<td>-0.0407</td>
<td>-2.76a</td>
</tr>
<tr>
<td>Education of mother</td>
<td>0.0132</td>
<td>2.45b</td>
<td>0.0059</td>
<td>1.15</td>
</tr>
<tr>
<td>Age of mother</td>
<td>-0.0083</td>
<td>-3.87a</td>
<td>-0.0099</td>
<td>-4.83a</td>
</tr>
<tr>
<td>Age of head of HH</td>
<td>0.0054</td>
<td>3.39a</td>
<td>0.0063</td>
<td>4.15a</td>
</tr>
<tr>
<td>Sex of head of HH</td>
<td>0.3021</td>
<td>2.09b</td>
<td>0.1767</td>
<td>1.28</td>
</tr>
<tr>
<td>Dependency ratio</td>
<td>-0.0011</td>
<td>-3.61a</td>
<td>-0.0010</td>
<td>-3.25a</td>
</tr>
<tr>
<td>Female ratio in the HH</td>
<td>-0.0016</td>
<td>-1.46</td>
<td>-0.0003</td>
<td>-0.33</td>
</tr>
<tr>
<td>QUARTER1</td>
<td>0.0053</td>
<td>0.17</td>
<td>-0.001</td>
<td>-0.03</td>
</tr>
<tr>
<td>QUARTER2</td>
<td>0.0081</td>
<td>0.24</td>
<td>-0.0054</td>
<td>-0.17</td>
</tr>
<tr>
<td>QUARTER3</td>
<td>0.0035</td>
<td>0.11</td>
<td>-0.0076</td>
<td>-0.24</td>
</tr>
<tr>
<td>Cereals area</td>
<td>0.0001</td>
<td>2.78a</td>
<td>0.0001</td>
<td>3.97a</td>
</tr>
<tr>
<td>Pulse area</td>
<td>0.0061</td>
<td>1.81c</td>
<td>0.008</td>
<td>2.49b</td>
</tr>
<tr>
<td>Constant</td>
<td>8.5542</td>
<td>43.25a</td>
<td>5.7025</td>
<td>29.18a</td>
</tr>
<tr>
<td>R square</td>
<td>0.493</td>
<td>0.473</td>
<td>0.753</td>
<td>0.946</td>
</tr>
</tbody>
</table>

1 Natural log of the variable is used.

a, b, and c sig. at 1%, 5%, and 10% level, respectively.
relevant determinants of micronutrients than of macronutrients. Family size and dependency ratio have negative and significant impact on nutrition intake per adult-equivalent. The R-square value shows that the estimated model captures most of the important determinants of nutrient intake.

**Impacts on Health Indicators**

The determinants of the nutritional status were estimated by regressing potential explanatory variables on the anthropometric measurements. There are difficulties in capturing essential variables explaining the health status of an individual. According to Shils et al. (1994), these variables may be physical, social, and emotional problems, which may interfere with appetite or may affect the ability to purchase, prepare, and consume adequate diet. Equitable access to consumption among the members of the household is an important factor, which is hardly captured in the model, due to the lack of data. Due to such difficulties, the econometric models of health and nutritional status are generally weak and R-squares ranging between 10% to 15% are supposed to be good estimates (Von Braun, Haen, and Blanken, 1991).

In this study, the values of the Z-scores (Height-for-age, weight-for-age, weight-for-height) computed from the anthropometrics measurements were used as a dependent variable and the nutrition intake discussed above, the KAP (mother’s knowledge, attitude and practice) sex of the index child, age and education of the mother, participation of the mothers in village health program, vaccination during pregnancy, and specific knowledge of the role of balanced diet were used as explanatory variables. The estimated model shows that the weight-for-age (WAZ) and weight-for-height (WHZ) Z-scores, which reflects the current nutritional status, resulted in more efficient estimates of the model parameters (Table 4).

The result shows that KAP (mother’s knowledge, attitude, and practice), age of the mother and female headship are important determinants of the WAZ and WHZ scores. Participation in the village health program has a significant effect (at 10% level) on the WHZ score. Unexpected sign of coefficients on protein and on β-carotene intakes were observed in the two models. In addition to targeting the income side to improve the nutritional status of the members of a household, intervention strategies should take the gender and the health aspects into consideration.

**CONCLUSION**

This paper assesses the impact of adopting market-oriented dairy technologies (cross bred cows and associated feed and management packages) on food
security. Food security is measured in terms of increased income, increased expenditures on food and non-food products, increased nutrient intakes, and better health status.

Results of econometric estimations using a recursive estimation procedure indicate that the proportion of crossbred cows owned, is an important determinant of income. Also resource bases like cultivated areas and purchased inputs, which are mainly obtained through the cash generated from dairy products, are important determinants of per capita income. Access to market is also an important factor determining the level of per capita income. Access to crossbred cows via income changes significantly and positively influences expenditures on food and non-food items and nutrient intakes. The higher the income level, the higher the expenditure on food and non-food items. Except for calorie intakes, higher expenditure on foods has had positive effects on other nutrients intakes. However, increased prices of food have had negative impacts on nutrient intakes. Finally, mother’s knowledge, attitude and practice, age of mother, and gender of the household heads are important determinants of health status.

NOTE

1. Birr is the legal Ethiopian currency. At this time, 1 US dollar is about 8.3 Ethiopian Birr.

### TABLE 4. Determinants of Nutritional Status of Children Under 6 Years

<table>
<thead>
<tr>
<th>Variables</th>
<th>HAZ-Score</th>
<th></th>
<th>WAZ-Score</th>
<th></th>
<th>WHZ-Score</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \beta )</td>
<td>( t )</td>
<td>( \beta )</td>
<td>( t )</td>
<td>( \beta )</td>
<td>( t )</td>
</tr>
<tr>
<td>Constant term</td>
<td>-3.823</td>
<td>-2.85a</td>
<td>-2.688</td>
<td>-2.73a</td>
<td>-0.679</td>
<td>-0.73</td>
</tr>
<tr>
<td>Sex (male =1; female = 2)</td>
<td>-0.148</td>
<td>-0.51</td>
<td>-0.399</td>
<td>-1.87c</td>
<td>-0.420</td>
<td>-2.07b</td>
</tr>
<tr>
<td>Age of mother</td>
<td>0.033</td>
<td>2.19b</td>
<td>0.028</td>
<td>2.50b</td>
<td>0.010</td>
<td>0.98</td>
</tr>
<tr>
<td>Education level of mother</td>
<td>0.024</td>
<td>0.33</td>
<td>0.035</td>
<td>0.65</td>
<td>0.016</td>
<td>0.33</td>
</tr>
<tr>
<td>KAP</td>
<td>0.046</td>
<td>0.39</td>
<td>0.191</td>
<td>2.20b</td>
<td>0.221</td>
<td>2.70a</td>
</tr>
<tr>
<td>Per capita protein intake</td>
<td>0.023</td>
<td>1.94c</td>
<td>0.001</td>
<td>0.12</td>
<td>-0.013</td>
<td>-1.60</td>
</tr>
<tr>
<td>Per capita iron intake</td>
<td>-0.007</td>
<td>-1.33</td>
<td>0.002</td>
<td>0.48</td>
<td>0.008</td>
<td>2.09b</td>
</tr>
<tr>
<td>Per capita ( \beta )-carotene intake</td>
<td>0.002</td>
<td>0.47</td>
<td>-0.003</td>
<td>-1.08</td>
<td>-0.006</td>
<td>-2.12b</td>
</tr>
<tr>
<td>Knowledge of advantage of balanced diet (know = 1; 0 otherwise)</td>
<td>0.008</td>
<td>0.02</td>
<td>0.341</td>
<td>1.11</td>
<td>0.427</td>
<td>1.47</td>
</tr>
<tr>
<td>Participation in village health (yes = 1; no = 0)</td>
<td>-0.195</td>
<td>-0.44</td>
<td>0.298</td>
<td>0.91</td>
<td>0.572</td>
<td>1.84b</td>
</tr>
<tr>
<td>Vaccination during pregnancy (yes = 1; 0 = no)</td>
<td>0.451</td>
<td>1.37</td>
<td>0.016</td>
<td>0.07</td>
<td>-0.257</td>
<td>-1.12</td>
</tr>
<tr>
<td>R square</td>
<td>0.19</td>
<td>0.22</td>
<td>0.29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a, b, and c indicate statistical significance at 1%, 5%, and 10%, respectively.
REFERENCES


