Economic and nutritional impacts of market-oriented dairy production in the Ethiopian highlands

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Table of Contents

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Executive summary

A recursive empirical analysis was applied based upon a detailed survey of 57 and 90 households in 1997 and 1999, respectively, in the Holetta area in the highlands of Ethiopia. The results of the analysis indicate that adoption of crossbred cows and complementary feed and management technologies along with crop area, labour supply and use of inputs is a significant determinant of per capita income. Variability of expenditure on purchased food is explained by household income, area allocated to food crops, proportion of cash income in total income, distance to the nearest crop market as well as socio-economic characteristics of the household. Household income and proportion of cash income principally determined expenditures on non-food and farm and livestock inputs.

Cash expenditure on food, and the unit price of nutrient are important determinants of per capita calorie, protein and iron intakes. Furthermore, household demographic characteristics such as gender of the head of the household and age of the mother play a significant role in the nutrient composition of consumed food.

The results indicate that market-oriented activities moderately reduce poverty and improve food security and nutrition of smallholder households. Through its impact on the expenditure of inputs, market-oriented dairy production may also lead to increased intensification of crop production and further improves incomes and nutrition. Agricultural development strategy of the country should take this option into consideration. Moreover, such introduction has the potential of stimulating the rural economy through the increased demand for non-food. Success of such activity depends on availability of marketing infrastructure to encourage smallholders’ market participation.

1 Introduction

In many developing countries, poverty, food insecurity and poor nutrition are persistent problems especially among the rural population predominantly dependent on low productive semi-subsistence farming. The situation is probably worst in Ethiopia. The highlands of Ethiopia are one of the densely populated and poorest regions in the world with per capita income a little over US$ 100 (World Bank 1996). Chronic malnutrition (stunting), far more common than acute malnutrition (wasting), is found in 64.2% of all children, making it the third highest in the world (Pelletier et al. 1995). These problems and their associated manifestations in the people's livelihood and wellbeing are of staggering proportions and many economists and policy makers view that improving household income is an appropriate entry point. This view holds if higher household incomes translate into better nutrition and health for the household since food-based approaches to combating macro- and micro-nutrient deficiencies are often more sustainable than supplementation (Neumann et al. 1993). One such conceivable food-based route to income improvement, especially among rural farmers, involves technological change to increase yield and output and greater participation in market.

Whether economic gains brought by technological change and commercialisation in agriculture work their way through to the poor is still debated (Binswanger and von Braun 1991). It is possible to be highly market oriented yet derive only subsistence level income and consumption. It is widely argued in a large body of the literature that commercialisation of agriculture has mainly negative effects on welfare of the poor (von Braun 1995). In contrast, Binswanger and von Braun (1991) contended that normally technology and commercialisation stimulate agricultural growth, improve employment opportunities and expand food supply—all central to the alleviation of poverty. Apparently, technology and commercialisation, through growth, bring benefits to the poor if accompanied by appropriate policies.

Despite the growing body of studies on determinants of household food consumption, nutrient intakes and health in developing countries in recent years (see Behrman and Deolalikar (1988) for review of early work), little is yet known about the influence of adoption of production technologies on these variables. Some studies have examined the effect of agricultural commercialisation on nutrition of the rural poor (Bouis and Haddad 1990; von Braun 1995). This paper examines how income increments derived from technology adoption and participation in market-oriented activities, namely improved dairy production, affects expenditure and nutrition of poor households. It quantifies, recursively, the links between adoption of new dairy technologies, increased household income, expenditure on food, non-food and inputs and improved human nutrition as measured by calorie, protein and iron intake in the Holetta area of Ethiopia. Unlike the previous studies, this paper explicitly accounts for the role of technology adoption on expenditure and nutrient intakes.

The next section illustrates the conceptual framework used in the analysis. Section 3 presents a simple empirical econometric model for estimation of the various relationships investigated. Data used are described in Section 4. Section 5 presents the econometric results and Section 6 summarises the results and their policy implications.

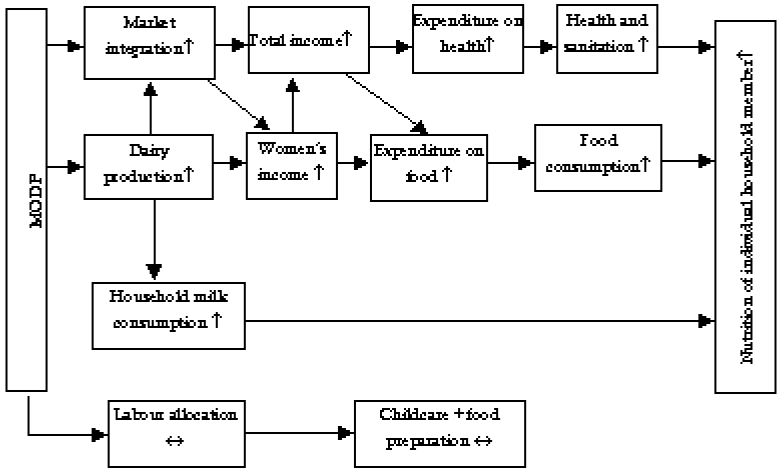
2 Commercialisation, technological change and nutrition

Gains in real income from technological change or commercialisation may translate into food consumption of the poor and nutritional welfare of children. However, in targeting nutritional welfare of rural population, the diverse diet of the poor has frequently been underestimated in the past. The nutritional characteristics of commodities consumed need to be seen in the context of the total diet of the poor (Binswanger and von Braun 1991). In this context, the essential role of livestock products seems to have been overlooked in the early attempt to improve the nutrition of the poor that have focused on plant production and the effort to increase the protein content and the content of certain amino acids in cereals.

Livestock products, especially dairy, can make unique contribution to human nutrition of the poor in developing countries by providing micronutrients in bio-available form such as Vitamin A, in addition to carbohydrates, protein and calcium. Thus, dairy development and improved technology directly contributes to improving the nutrition of dairy producers by making more milk available for home consumption. However, the indirect effects on consumption and nutrition are also important. Poor smallholder dairy producers may trade expensive calories (milk and meat) for cheap calories (cereals), thereby, improving total food consumption (Alderman 1987). Thus, milk and other dairy products become important sources of cash leading to an increased commercialisation of subsistence farming. The favourable effects on nutrition arise from the link between commercialisation and income rather than directly from the effect of technology on production (Binswanger and von Braun 1991).

In the mixed crop–livestock system of the Ethiopian highlands, livestock is an important source of draft power for crop production, cash income from sale of live animals, dairy and animal products for household consumption. The introduction of crossbred cows and complementary feed and management technologies for increased dairy production results in commercialisation of smallholder farms. The milk produced is treated as a cash commodity and integration into the market occurs. Such intensified, market-oriented dairy production (MODP) has the potential to make smallholder-farming systems more viable and sustainable (Shapiro et al. 1998). The introduction of these technologies substantially raises milk production and incomes where development efforts are market-oriented and demand-driven (Shapiro et al. 1998; Tangka et al. 2002).

Figure 1 illustrates the conceptual framework of the impact of MODP at the household level. High productivity of crossbred cows and complementary technology result in a higher milk and dairy production for consumption and sale. Adopting households may use the increases in cash income to buy food and pay for other household needs and farm inputs. The impact of dairy technology on nutrition and health may result from direct increases of household consumption of milk and dairy products. The impact can also be indirect through higher household expenditure on food, health and sanitation.



Notes: hypothesis:

Figure 1. *The linkages between the introduction of market-oriented dairy production (MODP) and household impacts.*

It has been well established by nutritionists that consumption of more dairy products results in a better human nutrition and health (Neumann et al. 1993). Thus, children of the adopting households who consume more dairy products are expected to be healthier. However, the nutrition and health impacts of increased milk and dairy production on individual members depend on intra-household resource allocation, income distribution, pattern of expenditures made with the increased income and nutrient intakes. The interactions between these intra-household decisions and individual outcomes need to be considered to ensure that all household members are reaping the potential benefits.

3 Theoretical model

As is now common in the literature, the reduced form equations for household consumption, nutrient intake and health status can be derived for household model that encompasses household production and consumption decisions. This approach assumes a joint household utility function (Pitt and Rosenzweig 1985; Senauer et al. 1988).

Following the specification of the basic household model introduced by Singh et al. (1986), the household maximises the following utility:

$$U = U(C_o, C_p, C_{nf}, C_l, Z) \quad (1)$$

where C_o is household produced food consumption, C_p is purchased food consumption, C_{nf} is consumption of non-food goods and services, C_l is leisure and Z is household characteristics such as age, gender and education of the head of the household and household size and composition affecting tastes and preference. The utility function is maximised subject to an income constraint (2), production function (3) and labour endowment constraint (4):

$$P_o C_o + P_p C_p + P_{nf} C_{nf} + rI = P_o Q \pm w(L - F) \quad (2)$$

$$Q = Q(L, A, I) \quad (3)$$

$$C_l + F = T \quad (4)$$

where P_0, P_p, and P_{nf} are prices of food produced by the household, purchased food and non-food goods, respectively, r is the unit price of purchased farm inputs (*I*) such as seed and fertiliser, w is the wage rate, Q is the quantity of output produced by the household, L is labour input, A is farm area, *F* is family labour, and *T* is total household labour time. All prices, P_0, P_p, P_{nf}, *r* and *w* are assumed exogenous and not affected by actions of the household. Substituting the production constraints for *Q* and the time constraint for *F* into (2) yields:

$$P_o C_o + P_p C_p + P_{nf} C_{nf} + wC_l = wT + P_o Q(L, A, I) - wL - rI \quad (5)$$

where $P_o Q(L, A, I) - wL - rI$ is a measure of farm profit. The left-hand side of (5) is the total household expenditure on purchases of its own production, on market purchased food, market-purchased non-food good and service and purchases of its own time in the form of leisure. The right-hand side is a Becker's concept of full income. Since production decisions can be made independently of consumption and labour supply decisions, the first order conditions for labour input and purchased inputs can be solved for L and I in terms of output and input prices, the technological parameters of the production function and the fixed farm area (Singh et al. 1986). Let the solution for *L* and *I* be given by:

$$L^* = L^*(w, r, P_o, A) \quad \text{and} \quad I^* = I^*(w, r, P_o, A) \quad (6)$$

Substituting *L** and *I** into the right hand side of (5) to obtain the value of income when farm profits are maximised through an optimal choice of labour and farm inputs such that:

$$P_o C_o + P_p C_p + P_{nf} C_{nf} + w C_l = Y^* \quad (7)$$

where *Y** is profit-maximising full income. Maximising the utility function (1) subject to (7) and solving the first order conditions yields the standard demand functions of the form:

$$C_i = C_i(P_o, P_p, P_{nf}, P_{in}, w, r, Y^*, Z) \quad \text{for } i = o, p, nf, in \quad (8)$$

The demand for nutrients is derived directly from demand equation for food and can be represented as:

$$N_j = N_j(P_p, P_o, P_{nf}, Y^*, Z) \quad \text{for } j = \textit{calorie, protein, iron} \quad (9)$$

where *N* is the per capita household intake of nutrients.

The above specification is consistent with that of several empirical studies (see Senaur and Garcia 1991; Variyam et al. 1999; Tangka et al. 2002). Some elements of the above theoretical model are modified in the empirical specification to address pertinent issues specific to the problem to be analysed. This includes the impact of intensified dairying and market-orientation of smallholder farmers on per capita income, expenditures and nutrient intakes.

When all prices are exogenous to the household such as in perfect markets, the household behaves as if production and consumption decisions were made sequentially, i.e. separability of production and consumption decisions. Perfect markets are sufficient, but not necessary condition for separability. There is separability whenever prices are exogenous and markets are used, even if sale and purchase prices are not identical (Sadoulet and de Janvry 1995).

In the Ethiopian setting, the farming households are semi-subsistence, they retain a large part of their products for home consumption, market a small share of their output, usually in small quantities in local markets, and distribute their sales over the year. For the marketed part, they are price takers in all markets and their decisions exert no influence on the market for input and output. Therefore, whether the overall production– consumption behaviour is separable is still an empirical question and may be location- and enterprise-specific.

Tangka et al. (2002) assumed non-separability, and hence specified a non-recursive agricultural household model in examining the food consumptions, calorie intake and marketed surplus effects of market-oriented dairy production in the same study location. However, MODP technology enhances market participation both in input and output markets significantly compared to traditional, low-input, dairy system. Hence Tangka et al. (2002) assumed that production and consumption decisions are made separately by the sample of this study, thus the agricultural household models can be solved recursively. Bouis and Haddad (1990) employed recursive techniques for solving this type of problem.

Given the above theoretical model and the assumption of separability, the following issues are addressed recursively in assessing the impact of market-oriented dairy technologies in the highlands of Ethiopia, i.e.:

- the impact of the dairy innovation on household incomes
- the impact of incremental increases in income on food expenditure, non-food expenditure and input expenditure
- the impact of incremental increases in food expenditure on calorie, protein, and iron intakes indicating better access to food and perhaps leading to improved nutrition.

Because of the likelihood of the simultaneity problem, variables on the right hand side of each equation will 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 will 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). 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. The estimation procedures and the results are further discussed in the subsequent section.

4 Sampling framework and data

4.1 Sampling framework

The study site is located in the central highlands of Ethiopia, about 40 km west of Addis Ababa in the vicinity of Holetta town. The altitude of the research area is about 2600 metres above sea level (masl). Average annual rainfall is 1100 mm with mean daily temperature of less than 20ºC. The farming system in the study area is a typical mixed crop–livestock system with livestock playing an important role for provision of food (milk and meat), draft power, dung (which is used for soil fertility enhancement as well as fuel) and cash. The main crops are barley, wheat, teff, oats and horse beans. Other minor crops include field peas, chickpeas, linseed, sorghum and rapeseed. Farmers usually use manure, urea and diammoium phosphate for soil fertility management. These inputs are either used individually or in combination, depending on availability, type of soil of the plot and the crop grown.

Beside crops, the household keeps a herd of animals, mainly consisting of dairy cows, oxen for plowing, 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, adoption of dual-purpose (dairy and draft) crossbred cows and on-farm forage production were encouraged. This technology was expected to help farmers reduce herd size in order to increase the efficacy of feed use, while still maintaining the capacity for both animal traction and milk production.

The data used for this study were collected in 1997 and 1999 in association with the Holetta Dairy Development Project, a collaborative effort involving the Ethiopian Agricultural Research Organization (EARO), the International Livestock Research Institute (ILRI), the Ethiopian Ministry of Agriculture (MoA), and the Ethiopian Health and Nutrition Research Institute (EHNRI). On-station studies were conducted for several years on the biological performance of crossbred cows for milk production and traction. Once a feeding and management package was developed, on-farm testing was started in 1993 involving introduction of crossbred cows, improved feed technology such as production of forages, and improved management: feed supplements, veterinary services and extension. Initially 14 pairs of crossbred dairy cows were introduced to 14 households in Holetta, half for milk production only, and half for traction and milk production. In order to increase the scope of the project and assess adoption potential, in 1995, 120 more crossbred cows were sold on credit to an additional 59 households. Households other than those participating in the project also own crossbred cows. The participants were selected from a list of about 350 households from a number of villages around Holetta town who expressed interests in acquiring crossbred cows, showing that they have the resources to buy and care for them. From the perspective of this study, this group represented potential adopters who would have made the decision to adopt dairy and crossbred technology should they have access to it. The interested households were further stratified, according to their land, livestock and labour resources, into three wealth groups, namely relatively poor, medium and rich farmers. In addition to the initial 14 households selected in 1993, a total of sixty households were selected randomly with equal number in each wealth strata (20 households). As part of the technology package, improved management practices were introduced for the crossbred cows owners (oat/ vetch as forage, backyard fodder crops, and construction of improved barns).

In 1995, 60 control households using local zebu cows for milk production and oxen for traction were randomly selected and included in the household surveys. The location of the control households and their wealth ranking roughly match that of the participating households.

4.2 Data

Extensive data collection was carried out in the period 1995–97 and 1999. Information was obtained on crop production, livestock production, income generation from different sources, labour allocation to different activities and expenditures. In addition, a one-day and monthly, food intake survey was conducted in 1997 and 1999. Unfortunately, all households were not surveyed for all data. The sample households in this study include all households for which all the necessary data is complete in 1997 and 1999. This makes an irregular panel data of 57 households in 1997 and 90 in 1999.

Households participating in MODP, hereafter referred to as adopters, and the control group, hereafter referred to as non-adopters, were monitored for production, resource allocation, incomes and expenditures and price data between 1993 and 1999. Moreover, data on demographic, resources endowment, cropping and livestock activities were collected. Households were visited monthly (for ten months in 1997 and 12 months in 1999) to obtain food intake information for the previous day, on a 24 hours recall basis. Quantities of ingredients used for various recipes were recorded at the household level as well as the number of persons who consumed the food. Per capita average calorie intake was then calculated by summing the calorie content of the ingredients, netting out leftover, and dividing by the number of adult equivalent of persons consuming. Per capita calorie intake was averaged for the year to calculate average per capita intake. The same process was followed in calculating protein and iron. The nutrient content of the ingredients was obtained from the published nutritional tables for Ethiopia (EHNRI 1997).

Table 1 presents summary of the major variables used in estimating the functional relationships. The household earns income from production of crops and livestock including dairy, and renting of its resources such as land and labour. Crop production is a major source of income accounting for 61% of total household income. Whereas the share of crop production in total household income was as high as 67% for non-adopters, it was as low as 55% for the adopters. Animal production constitutes 34% of the income of the adopters, and only 15% for the non-adopters. The income per adult equivalent is generally low with a significant difference between the two groups of households, mainly attributed to the difference in animal production.

Table 1. *Mean value of the major variables used in the analysis of market-oriented dairy production (MODP) (1997–99) in the highlands of Ethiopia.*

Variable	All cases	Participants (adopters)	Non-participant (non-adopters)
Number of observations	147	78	69
Per capita income (Ethiopian Birr, ETB)[1]	1435	1663[a]	1178
Per capita expenditure on food	160	168	151
Per capita expenditure on non-food	169	178	159
Household expenditure on farm inputs	1199	1382[a]	988

Proportion of cash income	0.37	0.41[a]	0.32
Per capita nutrition intake			
Calorie (Calorie)	2354	2511[a]	2177
Protein (gm) Iron (mg)	72118	76a131[a]	67103
Farm area (ha)	2.97	3.32[a]	2.58
Area allocated to food crops (ha)	2.30	2.44[c]	2.15
Input use per hectare (ETB)	374.57	379.36	369.16
Local breed herd size (TLU)	6.23	5.55[b]	7.00
Number of crossbred cows	0.91	1.69[a]	0.00
Labour units in adult equivalents	3.09	3.06	3.13
Adult equivalent size of the household	5.79	5.72	5.89
Age of household head	45.45	46.00	44.83
Age of mother or spouse	37.10	37.03	37.17
Dependency ratio	0.39	0.40	0.38
Women ratio	0.48	0.45[b]	0.51
% illiterate head of households	0.29	0.26	0.32
% of heads with high school education	0.14	0.15	0.14

1. US$ 1 was approximately ETB 6.65 in 1997 and 7.90 in 1999.
a, b and c means of the two groups are significantly different at 1, 5 and 10% level respectively.
Source: ILRI, Dairy–draft project survey (1997–99).

Average annual per capita cash expenditure on food is about ETB 168 and 151 for adopters and non-adopters, respectively (Table 1). The figures are low mainly because these farm households consume most of their own production. In the adopters and non-adopters households, 67 and 66%, respectively, of the value of food consumed in 1999 was from own production (Tangka et al. 2002). The adopters have significantly higher cash expenditures on farm inputs including crop inputs such as seed and fertiliser, animal feed and veterinary services. This means that MODP may also lead to intensification of crop production through increased cash income that may be used for purchases of improved crop technologies.

Adopting households consume about 15% more calorie, 13% more protein and 27% more iron than non-adopters. These differences are statistically significant and are very positive contributions of improved dairy in a short period in a situation where income and consumption levels are low. Cumulative effects of such magnitude resulting from improved dairy have the potential to improve the lives of these poor farm households significantly over a longer period. As discussed earlier, the contribution of MODP to the nutrition may not only be through a direct consumption of milk but through substitution effects. Also, the diets may not change significantly as most households will stick to their usual diets. However, the main gains may be for the households that may face deficiencies in absence of MODP.

4.3 Explanatory variables

The explanatory variables used in the regression analysis were categorised into resources such as livestock holding size and composition, labour, land, 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 practices[1]. Among farm characteristics is its proximity to the nearest market.

1. Because data on mothers' knowledge, attitude and practice was not collected in 1999, this variable was assumed to be time-invariant.

Non-adopting households exclusively own indigenous cows while adopting households own both indigenous and crossbred cows. The number of local breed livestock, expressed in tropical livestock units (TLUs), ranges from 1.1 to 20.4, with a mean of 6.2. There is a significant difference between the livestock holding of adopters and non-adopters with a mean value of 5.55 and 7.00 TLUs, respectively.

The average cultivated area per household ranges between 0.4 and 4.6 ha with a mean of about 2.27 ha. There is a significant difference in land ownership between adopters and non-adopters. The average area cultivated by adopters is 3.3 ha as compared to 2.58 ha for non-adopters. Similarly, the cultivated area per adult equivalent is larger for the adopters. Food crops occupy about 77% of cultivated area of the adopters, which is significantly larger than that of the non-adopters. Hence, it is expected that crop production, which is a function of the area allocated to it, play a significant role in explaining the variation in expenditure on purchased food and nutrient intakes of the member of the household.

Family size is converted into adult equivalent (AE) measure to control for factors such as age, and sex of each of the members of the household. The family size in Ethiopia is usually large. The average household size in the study area is 5.72 and 5.89 AE for the adopters and non-adopters, respectively, although the difference is not statistically significant (Table 1). The AE was used to normalise relevant variables in computing the corresponding per capita measures of the variables used in the estimation. Except the ratio of females in the household, there is no significant difference between the two groups in the socio-economic characteristics of the household.

5 Results and discussion

A recursive econometric model was estimated based on the theoretical model presented earlier. All equations were estimated using ordinary least squares (OLS), and with the exception of expenditure on inputs, the others were estimated on per capita basis based on best fit of the relevant equations. Output and input prices were dropped given the limited variability across households, as most of the households operate in similar markets with fairly uniform prices.

5.1 Determinants of gross per capita income

In the recursive system, the gross per capita income is defined as the market value of crops and livestock production and income from all other sources (such as off-farm activities) and estimated as a function of productive resources and socio-economic factors. The productive resources are represented by factors affecting both crop and livestock production. This includes per capita cultivated area, input use (fertiliser, seed and chemicals) per unit area,[2] family labour supply, per capita size of the local breed herd and per capita number of milking crossbred cows owned. Since the total labour of the household is allocated to different activities to generate income or leisure, the family labour supply was computed by considering the working capacity of the different age categories and sex of each household member and was used as a factor determining income level. The input use per unit area represents the intensity of resource use for the production and, thus, variation in input use may influence income. The expenditure on inputs used for the production is calculated at time of incurring the same. Since farmers are expected to pay for inputs received on credit during the same cropping year, the value of the inputs received on credit was also considered.

> 2. Cropping season in the area begins in May/June through January of the subsequent year. Household crop income is defined here as the value of crop harvested at the beginning of the year,e.g.1997.Input use per hectare and crop area per capita in 1996–97 and 1998–99 cropping season are the relevant variables used in estimating the income equation (seed costs were estimated based on average seed rates in the area). This should be distinguished from input expenditure equation, which defines input expenditure during the years under consideration (1997 and 1999). Crop input in this expenditure are related to crop income at the end of the year but not at the beginning of the year.

The socio-economic characteristics of the household included in the estimation include age, sex and education of the household head. Round trip travel time to the nearest crop and livestock markets and a year dummy variable were also included in the equation. Logarithmic transformations of all continuous variables, with the exception of per capita size of the local breed cows and per capita number of milking crossbred cows owned, were used for the model estimation. This functional form (as in other forms equations in this study) is chosen because it provides the best fit to the data. Based on the VIF test, there is no serious multicollinearity between variables in the income equation. The variables in the income equation explain 73% of the variation in income among households.

Table 2 presents OLS estimates of the parameters of the income equation. All the traditional production factors have positive and statistically significant coefficients, as expected. Land appears to be the most important income source in this agrarian economy with an elasticity of 0.74. The estimated elasticity of income with respect to crop inputs is 0.41 and that of labour is only 0.13.

Table 2. *Determinants of per capita income in the highlands of Ethiopia.*

Variable	Parameter (b)	t-value
Constant term	5.781	7.397[a]
Per capita cultivated area[1]	0.743	10.623[a]
Inputs (seed, fertiliser, chemicals)[1] (ETB)	0.414	4.474[a]
Age of head of household (HH)[1]	–0.230	–2.132[a]
Education of head of HH (= 1 if illiterate)	–0.006	–0.062
Education of head of HH (= 1 if read and write without formal education)	–0.045	–0.588
Sex of head of HH (Male = 1, Female = 0)	0.079	0.567[a]
Per capita local breed of animals owned (TLU)	0.117	2.669[a]
Per capita crossbred cows owned (TLU)	0.510	3.199[a]
Family labour supply1	0.132	2.016[a]
Round trip travel time to crop market[1]	–0.137	–3.441[a]
Round trip travel time to livestock market[1]	0.101	1.340
Year (dummy)	–5.781	–4.760[a]
R-square	0.729	—
Adjusted R-square	0.705	—

1. Natural log of the variable is used in the estimation. Dependent variable is the natural log of per capita income.
a, b and c indicate statistical significance at 1, 5, and 10% levels, respectively.
Source: Estimated based on ILRI, Dairy–draft project, 1997–99.

As expected, adoption of dairy and associated technology is a significant determinant of household income. The estimated coefficient of 0.51 on per capita milking crossbred cows owned translates into an elasticity of income of 0.465 at the mean value of 0.91 per capita crossbred cows. This estimate is roughly consistent with the observed percentage difference between adopters and non-adopters. This is not surprising since the mean income of an adopting household is 41% higher than a non-adopting household (Table 1). The income contribution of crossbred cows is mainly from the additional milk sales.

Local breed herd also contributes significantly to per capita income in this mixed, crop–livestock system, as indicated by the positive and significant coefficient of per capita holding of local breed. The result is robust in that livestock is an integral part of the mixed production system, which is the mainstay of the livelihood of the rural population in Ethiopia. Local breed livestock may contribute to household income indirectly through provision of draft power to crop production and directly through animal and milk sale. Households with only local breeds generate on average only 15% of their income from livestock, mainly from live animal sales. However, the contribution of an additional unit of local breed is much smaller than that of a crossbreed cow.

Crop markets appear to be an important institution for rural households for facilitating profitable transactions and income-generating opportunities. The estimated coefficient of the distance to the nearest crop market is negative and statistically significant. Clearly, longer travel time to markets involves higher transaction costs in terms of labour time and transportation costs. The longer the travel time to crop market, the lower the per capita income of the household. Longer travel time may discourage cash transactions, constrain the flow of market information especially on prices and availability of inputs, add to transaction costs of purchases and sales, and take away labour from farm production activities. In this analysis, the estimated elasticity of income with respect to distance to crop market is –0.137. Age of the head of the households significantly reduces household income. Older heads of households tend to be conservative in new technology adoption decisions but are usually more experienced in farming.

Per capita income appears to vary significantly between years. As compared to 1999, per capita income is substantially lower in 1997 as indicated by the magnitude of the negative and statistically significant coefficient of the year dummy variable. Income variability may be due to price, output variability or both.

5.2 Determinants of expenditures

Household expenditure can broadly be disaggregated into expenditure on food, non- food, and farm inputs. Theoretically, expenditure on food should include value of food produced and consumed by the household and values of purchased food. However, due to lack of information on the value of food consumed from own production in the 1997 data, expenditure on food is defined here as cash expenditure on food purchases. To capture the impact of own food production on expenditure, the area allocated to food crop production was included in the model estimation. Non-food expenditure includes household expenses such as clothing, health care, education, and social contributions. Expenditure on farm inputs includes purchases of fertiliser, chemicals, seed, animal feed and veterinary services, but does not include purchases of livestock generally considered as capital asset of long-term nature. Equations of per capita expenditures on food and non-food and household expenditure on inputs were estimated as functions of per capita income, proportion of cash income in total income, per capita area allocated to food crops (as a proxy for home produced food), round-trip time to the nearest crop and livestock markets, household characteristics (female ratio, dependency ratio, and age, sex and education of the household head) and a year dummy variable. Using Hausman test (Hausman 1978), endogeneity of income was detected only in the case of expenditure on inputs and, thus, predicted per capita income is used in this equation rather than observed income.

The estimated parameters of expenditure functions are presented in Table 3. The coefficients of the income variable in the three equations are positive and statistically significant. Expenditure elasticity of income is highest in the case of farm inputs (0.994) and lowest for non-food expenditure (0.214). These results indicate that income increments from technology adoption and commercialisation do not necessarily translate fully into additional food purchases, but distributed among the alternative needs of the households. It is worth noting that doubling income almost doubled expenditure on inputs indicating the high priority for increasing future income earnings. This also reflects the willingness of households to adopt improved crop technology such as improved seed and fertiliser and the perceived high returns to investment in crop intensification. The high proportional increase in farm input expenditure from increments of income as a consequence of adoption of the dairy technology reflects the closer link between crop and livestock sub-systems and that livestock intensification through introduction of improved production technology may lead to intensification in crop production thereby increasing the overall household income.

The proportion of cash income in total household income measures the degree of market orientation of the households. Sales of dairy, livestock and crop surpluses are the major sources of household cash income. As the proportion of cash income increases, expenditure on both food and non-food significantly increases. However, the expenditure on inputs is not affected only by the proportion of cash income but also by credit, an alternative source for input purchases. Credit may be substituted for cash income allowing households to spend more on other expenditures. At the mean values of the explanatory variables, the elasticities of cash food and non-food expenditure with respect to the pro- portion of cash income are 0.296 and 0.605, respectively.

These results suggest that technologies that increase productivity of cash commodities such as dairy and other livestock technologies also encourage farmers' participation in the market through increased expenditures on food and non-food goods consumed by the household. This may have significant growth linkages in the rural economy.

While it increases expenditure on non-food significantly, area allocated to food crops, a proxy for consumption from own production, negatively affects expenditure on inputs but has no significant effect on food purchases. Here, households appear to invest in inputs such as fertiliser and improved seeds to increase their production of other crops (noug cake, rape seeds, vegetable and forage crops) rather than food crops (cereal and pulses) to generate cash. Alternatively, households that allocate more area to food may spend more on non-food, as these households are likely to produce sufficiently for their own consumption. As discussed above, availability of crop markets to facilitate transactions is an important factor in determining income. Travel time to livestock markets only significantly reduces non-food expenditure while travel time to crop market increases it. This may be an indirect effect as non-food expenditure may principally come from livestock sales and longer travel time discourages or reduces the income earned from this source and potentially spent on non-food.

Households with uneducated heads tend to spend significantly less on food than those with heads who can read and write or have formal education. However, households headed by people who can read and write but without formal education tend to spend much less on farm inputs than those with illiterate heads or with formal education. Older household heads tend to spend significantly less on farm inputs, reflecting conservative behaviour or lack of ability towards adoption of new technology. Male-headed households, however, are likely to spend more on farm inputs and non-food expenditure than female-headed households.

Table 3. *Determinants of per capita expenditures on food, non-food and farm inputs in the Ethiopian highlands.*

	Per capita purchased food expenditure[1]		Per capita non-food expenditure[1]		Household farm input expenditure[1]	
Explanatory variables	b	t-value	b	t-value	b	t-value
Constant	3.396[a]	3.002	4.125[a]	3.225	–3.125	–1.536
Per capita income[1]	0.341[a]	3.642	0.214[b]	2.015	–	–
Predicted per capita income	–	–	–	–	–0.994[a]	–4.901
Per capita area allocated to food	0.106	1.050	0.519[a]	4.563	0.390[b]	2.175
Proportion of cash income	0.809[a]	3.379	1.650[a]	6.095	–0.311	–0.969
Distance to crop market	–0.044	–0.875	0.074	1.302	–0.012	–0.168
Distance to livestock market	–0.026	–0.291	–0.180[c]	–1.791	0.082	0.687
Age of head of household (HH)	–0.048	–0.364	–0.152	–1.026	0.533[a]	3.016
Sex of the head of HH	–0.168	–0.896	0.386[c]	1.820	0.442[c]	1.752
Education of head of HH (= 1 if illiterate)	–0.239[b]	–2.187	–0.035	–0.281	–0.178	–1.210
Education of head of HH (= 1 if read and write without formal education)	–0.065	–0.689	–0.083	–0.777	–0.227[c]	–1.766
Dependency ratio	–0.185	–0.949	–0.056	–0.253	–0.299	–1.138
Women ratio	–0.114	–0.561	0.260	1.135	0.301	1.107
Year (= 1 if 1997 and = 0 if 1999)	–0.544[a]	–7.623a	–0.066	–0.813	–0.023	–0.235
R-square	0.553	–	0.499	–	0.379	–
Adjusted R-square	0.513	–	0.454	–	0.323	–

1. Natural log of the variable is used.
a, b and c indicate statistical significance of the coefficient at 1, 5 and 10% levels, respectively.
Source: Estimated based on ILRI, Dairy–draft project, 1997–99.

Temporal seasonality also plays a significant role in food expenditure decisions. House- holds spent significantly less on food in 1997 as compared to 1999. This is consistent with the results of the income equation. Households earned higher income in 1999 and spent more on food purchases. However, the higher income in 1999 may reflect the higher commodity prices[3] rather than higher crop yields. Comparison of annual prices indicates that average price of all crops were higher in 1999 than in 1997. This is likely to be reflected in food intake and, consequently, nutrient intake, of the household.

3. We ignored the low levels of inflation in Ethiopia between 1997 and 1999 in comparing crop prices.

5.3 Nutrition intakes

The study hypothesises that the income impact of adoption of dairy technology transmits, recursively, through expenditure effects to nutrient intake. Average per capita daily calorie, protein, and iron intake were estimated as functions of per capita cash expenditure on food, unit price of the respective nutrients, area allocated to food (cereals and pulses) as a proxy for own food produced, and socio-economic factors of the household (such as age and education of the mother, sex of the head of the household and dependency and female ratios). Though little variability in prices of products was observed, the household may substitute expensive for less expensive food in order to increase the quantity of food intake. Therefore, the amount of food consumption is a function of prices, and the price per unit of nutrient is expected to be an important determinant of nutrient intake. Per unit price of the nutrient was computed as:

$$P_n = \sum_k P_k Q_k \Big/ \sum_k c_{nk} Q_k$$ for *n = calorie, protein, iron*

where P_k and Q_k are market price and quantity of the k^{th} food item consumed, respectively, and c_{nk} is the n^{th} nutrient content of the k^{th} food item. That is, the unit price is the total cost of food consumed divided by its content of specific nutrient. Prior to estimation of the consumption function, Hausman test was applied to test for endogeneity of food expenditure. The results show that the coefficient of the predicted per capita expenditure on food is statistically significant providing statistical basis for using instrumental variable technique in the estimation of the models.

The parameter estimates revealed that expenditures on food is significant determinant of the intake of all three nutrients, with estimated elasticities of 0.317, 0.326 and 0.193 for calorie, protein and iron, respectively (Table 4). This supports the study hypothesis that increasing household incomes through adoption of improved dairy technology leads to improving household nutrient intakes and, therefore, contributes to better nutrition and health. Given the elasticity estimates obtained, doubling the number of crossbred cows raised by the household translates into 5.0, 5.2 and 3.1 percent increase in calorie, protein and iron, respectively.[4]

4.¶ Let the elasticity of income with respect to crossbred cows, $\xi_{y,dc}$ be given by $\frac{\partial y}{\partial dc} = \frac{dc}{y}$, the elasticity of food expenditure with respect to income, $\xi_{E,y}$, be given by $\xi_{E,y} = \frac{\partial E}{\partial y}\frac{y}{E}$, and the elasticity of nutrient intake (N_i) with respect to food expenditure, $\xi_{Ni,E}$, be given by $\xi_{Ni,E} = \frac{\partial N_i}{\partial E}\frac{E}{N_i}$. Then the elasticity of nutrient intake with respect to crossbred cows, $\xi_{Ni,dc}$, is given by $\xi_{Ni,dc} = \xi_{y,dc}\,\xi_{E,y}\,\xi_{Ni,E}$.

Table 4. *Determinants of per capita intakes of calorie, protein and iron in the Ethiopian highlands.*

	Calorie[1]	Protein[1]	Iron[1]

Variables	b	t-value	b	t-value	b	t-value
Constant	7.716[a]	7.704	6.340	6.503	7.006	4.901
Predicted per capita food expenditure[1]	0.317[a]	4.309	0.326[a]	4.559	0.193[c]	1.844
Per capita area allocated to food[1]	0.077[b]	1.971	0.076[b]	2.005	0.142[b]	2.550
Proportion of cash income	0.038	0.289	–0.005	–0.040	0.271	1.456
Unit price of energy (ETB/kcal)	–0.394[a]	–2.941	0.260[b]	1.993	–0.196	–1.025
Unit price of protein (ETB/100 gm)	–0.115	–0.543	–0.767[a]	–3.705	–0.110	–0.362
Unit price of iron (ETB/100 mg)	–0.081	–1.146	–0.047	–0.682	–0.704[a]	–6.997
Travel time to crop market1 (min)	0.028	0.961	0.036	1.276	–0.030	–0.712
Travel time to livestock market[1] (min)	–0.117[b]	–2.254	–0.124[b]	–2.444	–0.091	–1.220
Age of the mother[1] (yrs)	–0.109[c]	–1.703	–0.102[c]	–1.634	–0.056	–0.614
Mother's education (= 1 if illiterate)	0.016	0.307	0.001	0.026	0.043	0.575
Mother's education (= 1 if read and write without formal education)	–0.008	–0.136	–0.015	–0.259	0.064	0.734
Sex of the household head (= 1 if male)	–0.159[c]	–1.679	–0.165[c]	–1.792	–0.127	–0.941
Dependency ratio	0.169[c]	1.720	0.152	1.587	0.103	0.733
Women ratio	–0.150	–1.491	–0.150	–1.538	–0.214	–1.493
Year (= 1 if 1997 and = 0 if 1999)	0.419[a]	5.683	0.396[a]	5.515	0.728[a]	6.918
R-square	0.517	–	0.433	–	0.653	–
Adjusted R-square	0.461	–	0.369	–	0.614	–

1. Natural log of the variable is used.
a, b and c indicate statistical significance of the estimate at 1, 5 and 10% levels, respectively.
Source: Estimated based on ILRI, Dairy–draft project, 1997–99.

There is a significant and negative relationship between the unit price of the nutrients and their intakes. The demand for these nutrients is relatively inelastic with own price elasticities of –0.394, –0.767 and –0.704 for calorie, protein and iron, respectively. This reflects the degree of response of the household to the cost of meals of high nutritive value such as meat, dairy and vegetables. This may explain the fact that households with dairy crossbred cows consume 22% more milk than households without crossbred cows, probably due to the perceived lower cost of their own production. This also supports an inverse relationship between the cost of food and the quantity consumed by the household. Unfortunately, these elasticities cannot be compared to estimates from other studies as in these studies commodity prices were used directly as regressors. The estimates obtained here are with respect to a weighted price index that depends on the cost of individual ingredient used in meal preparation.

Nutrient intakes significantly increase as household food production increases as measured by area allocated to food crops. This is clearly because food produced on farm constitutes the major source of household food consumption and, hence, nutrient intakes. However, the elasticity estimates are lower for protein and calorie compared to that of iron. Endogeneity of area allocated to food is rejected, supporting the hypothesis that area allocated to food is an exogenous factor in nutrient intakes decisions.

There is an inverse and statistically significant relationship between the age of the mother and per capita protein and calorie intakes. This may be due to the likelihood of young mothers receiving more formal education and more exposure to nutritional information. Male-headed households tend to consume significantly less energy and protein while households with more children consume significantly more calories, as indicated by the regression coefficients (Table 4).

Nutrient intakes vary significantly between the two years with higher intakes in 1997. This is expected since the higher income and, consequently, higher expenditure on food, in 1999 may have resulted from higher prices rather than increased yields. Households appear to adjust their nutrient intakes according to food supply situation. The implication of this is that alternative means to protect households from fluctuating nutrient intake due to variability in yield is required. For instance, income diversity from sources other than crops such as dairy and livestock is a critical element of food security.

6 Conclusions

This paper assessed the impact of adopting market-oriented dairy production (MODP) technology, consisting principally of crossbred cows and improved feed and management practices, by smallholder households in rural Ethiopia on income, expenditures and nutrient intake (i.e. energy, protein and iron). The results of a recursive relationship estimation demonstrate that adoption of MODP technology significantly raises per capita income, and income effect extends positively to expenditure and nutrient consumption. The higher the income level, the higher is the expenditure on food and non-food items and farm inputs. Purchased food expenditure is directly related to nutrient intakes.

The impact of crossbred cows on average household nutrient intake was relatively small but significant. The small changes in nutrient intake may be due to several factors. First, the number of milking crossbred cows in the study area is still small. Second, the low crop yields, which represent an important source of nutrients of 1999 season, may have forced households to adjust their food intake downward. However, the magnitude of nutrient intake increase might have been much larger for poorer households in the sample and for children in general, who are normally given priority in case the household have increased output and income. But information on these aspects was not recorded in disaggregated manner.

Overall, the results indicate that introduction of MODP technologies has the potential of stimulating the rural economy through increased demand for non-food. Success of such activities in combating poverty and food insecurity depends on availability of marketing infrastructure and availability of farm inputs and necessary veterinary services for dairy farmers. Policies that encourage farmers' participation in markets and generation of cash income appear to be critical. The MODP also may be linked to increased intensification of crop production as implied by the recursive impact of incremental increase in income on purchases of inputs. Agricultural extension programmes should also take this option into consideration.

The analysis falls short of addressing the intra-household allocation of benefits from adoption of the technology as well as the impact of technology adoption on health and growth of children in the adopting households. Future research should address these problems. For data limitation, cash expenditure is used as a proxy for total food expenditure. Though the results obtained here are consistent with economic theory, the magnitude of the coefficient should be interpreted carefully as it indicates the effect of only cash expenditure on food, but not food produced and consumed by the household.

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