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Hailemariam Teklewold

Abstract

We investigated crossbreeding adoption and milk and milk product market participation using farm household survey data in the central highlands of Ethiopia. We estimated a multivariate probit model to account for correlations across the choice of crossbreeding technology and market participation and to study the effect of transaction costs on participation. Our empirical results suggest that technology adoption and market participation decisions are correlated.We find complementarity between crossbreeding adoption and fresh milk marketing, and substitutability between fresh milk and milk product marketing. We also find that participation in fluid milk marketing is more likely if the milk collection point is close by. If farmers are far from the collection point, however, they are more likely to sell milk products (such as cottage butter and cheese). Adoption of crossbreeding is less likely if farmers are more risk averse. The study provides information for policy options to improve farmers' returns to agricultural production.

Key Words: technology adoption, market participation, transaction cost, livestock, Ethiopia

JEL Codes: Q13, Q16

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On the Joint Estimation of Technology Adoption and Market Participation under Transaction Costs in Smallholder Dairying in Ethiopia

Hailemariam Teklewold*

1. Introduction

Questions regarding small-scale dairy production, processing, and marketing have taken on renewed urgency as policy-makers and development practitioners seek ways to enhance productivity and returns through stimulating smallholders' technology adoption and market participation. This study jointly estimates dairy farmers' decisions about technology adoption (specifically, crossbreeding) and market participation among smallholders in Ethiopia, examining the complementarity and substitutability of these choices.

Transaction costs in relationship to both technology adoption and market participation are caused largely by poorly functioning rural institutions that constrain smallholders' access to input and output markets (de Janvry et al. 1991; Sadoulet and de Janvry 1995; Barrett 2008). In Africa, relatively high marketing costs for fluid milk, the thinness in fluid milk markets, and the risks attached to marketing perishables in the tropics suggest that transactions costs play a central role in the growth of smallholder dairy production and marketing (Staal et al. 1997; Holloway et al. 2005). Interventions aimed at facilitating smallholder organization, reducing the costs of inter-market commerce, and improving poorer households' access to improved technologies and productive assets are central to stimulating smallholders' market participation and escape from semi-subsistence poverty traps in the region (Barrett 2008). Understanding the various constraints affecting the choice of technologies and market participation is thus central to improving the dairy production and marketing environment.

Some empirical studies have examined the adoption of crossbreeding (Abdulai et al. 2005; Abdulai et al. 2008) and participation in dairy product marketing (Holloway et al. 2000; Lapar et al. 2003) in developing countries. However, in analyzing one of these decisions, the available studies usually consider the other decision as given; they also fail to consider the possibility of alternative market outlets. Therefore, estimating a model with a single equation of

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technology adoption with market participation as an explanatory variable is subject to simultaneous equation bias.

Building on the existing literature, therefore, two important points motivated this study. First, studies of participation in the dairy market usually ignore smallholders' decisions about which products to sell along the product chain. Farmers basically have to choose between participating in raw milk marketing or milk products marketing, which requires processing their milk output into cottage butter and cheese. An interesting feature of market participation is that smallholders regularly engage in the low-return, home-based processing of milk rather than directly marketing raw milk, which has a higher market return.[1] Despite the higher returns to fresh milk, the nature of milk – perishable and bulky – and the transaction costs that limit access to the fluid market might push farmers toward milk processing (Holloway et al. 2000).

Second, there has been little attempt in agricultural and development economics to empirically examine the correlations between farmers' technology adoption and market participation decisions. In fact, in their review studies, Barrett (2008) and Dorfman (1996) underscored the close interdependence between markets and technologies. A household's production technology choices fundamentally affect its market participation choices by affecting its productivity, and the returns on adoption of improved production technologies are fundamentally influenced by the nature of the market.

This paper's main contributions to the agricultural and development literature are the joint consideration of technology adoption and market participation and the consideration of market participation with different products. The decision whether to sell agricultural produce directly or to process produce into another form is a critical aspect of agricultural marketing that has seldom been studied in developing countries. From a policy viewpoint, this is important because the livelihood of many poor farmers the world over depends on the sale of agricultural commodities, yet widespread market failures that lead to substantial transaction costs (Fafchamps and Hill 2005; de Janvry et al. 1991) affect farmers' choices of what products to sell and their decisions to adopt technology. In an argument similar toFafchamps and Hill (2005), if

[1] While a more in-depth multivariate analysis is required, a non-parametric analysis of our survey data showed that fresh milk marketing may be remunerative. Cumulative distribution of returns from fresh milk selling dominates the cumulative distribution of returns from milk product marketing. This is shown by the graph of the cumulative density function (CDF) of returns from fresh milk marketing, which is constantly below that of returns from milk product selling (Fig. 1). The average return from fresh milk marketing is significantly higher than selling milk in processed form (4.99 Birr1/lit. vs. 2.76 Birr/lit.).

farmers receive a lower return because they sell a processed product, their welfare could be improved by offering institutional innovations to promote fluid milk sales, such as incentivized dairy marketing cooperatives or the involvement of the private sector through establishing nearby milk collecting centers.

Our paper applies a multivariate framework to test the correlation of farmers' decisions on adoption of crossbreeding technology and participation in milk and milk products marketing. We believe that understanding the correlations among decisions about technology adoption and market participation in this framework can be used to evaluate the complementarity and substitutability of decisions among crossbreeding adoption and participation in fresh milk and milk product marketing.

The paper proceeds as follows. Section 2 is an overview of smallholder dairy activities in Ethiopia. Section 3 presents the modeling framework. Sections 4 and 5 present the data and descriptive statistics. Section 6 presents results and discussion, while Section 7 presents policy implications and concludes.

2. Overview of Smallholder Dairy Production and Marketing

Ethiopia has great potential for dairy development due to its large livestock population, the favorable climate for improved, high-yielding animal breeds, and the relatively disease-free environment for livestock (Ahmed et al. 2004).[2] In Ethiopia, dairy cows are used mainly for breeding replacement of draught oxen and for milk production. Dairying in Ethiopia is predominantly a smallholder activity, in terms of both milk production and volume of sales. Annual national milk production from both urban and rural dairy production systems was estimated at 1.5 million tons, equivalent to USD $398.9 million (FAOSTAT 2007). The rural dairy system, which includes pastoralism, agro-pastoralism, and the mixed crop-livestock farming system, constitutes 97% of the total national milk production and 75% of commercial milk production (Ahmed et al. 2004). There are also significant commercial and aid imports of powdered milk (Azage and Asfaw 2004).

Propelled by the government's intention to transform smallholder subsistence production into a market-oriented dairy production system, the smallholder dairy sub-sector in Ethiopia has experienced some changes in the last few years. Efforts have been undertaken to increase the

[2] See Ahmed et al. (2004) for a review of the historical profile of the dairy sector in Ethiopia.

dairy productivity of smallholder farmers of Ethiopia. A number of development and research projects have taken place, including the smallholder dairy development project and the Selale dairy development project. One such effort was the introduction of a package of dairy production technologies that included crossbreeding indigenous breeds (Borana, Barca, and Horro) with exotic breeds (Fersian, Jersey, and Simmental). The system also promoted the introduction of improved feeding and management practices into the farming system. The development and availability of a package of improved production practices for smallholder dairying has been continued by national and international research activities. In addition, the advent of smallholder dairying in some parts of the country (such as Holletta, DebreZeit, Mojo, Kaliti, Koka, etc.) has also created opportunities for some farmers to specialize in producing feed for dairy cattle in the areas.

Milk processing is also a growing industry in some parts of the country. Both state and private dairy development enterprises in Ethiopia collect milk from dairy farms, mostly from farms in urban and peri-urban areas, and to a lesser extent from rural areas. In response, currently a number of commercial dairy farms are emerging in urban and peri-urban areas, and the numbers of smallholder rural dairy farms are also increasing in areas that have market access (Azage and Asfaw 2004). In recent years, promotional efforts have focused on institutional innovations aimed at developing and expanding an efficient marketing system and organizing farmers into milk producing, processing, and marketing cooperatives.

Milk marketing cooperatives have been established by the dairy development projects with the support of the Finnish International Development Association (Ahmed et al. 2004). These groups buy milk from both members and non-members, process it, and sell products to traders and other consumers. The groups also participate in value chains and process milk into cream, skim milk, sour milk, butter, and cottage cheese. This is a very important value addition compared to the traditional household-based processing methods, in which farmers mainly produce saturated butter and cottage cheese. By enhancing the ability of smallholder farmers to reach markets, and by reducing transaction costs associated with sparsely populated rural areas, remoteness from towns and markets, high transport costs, lack of information about markets, and lack of negotiating skills, collective organization can break one of the most pressing dairy development challenges.

3. Conceptual and Econometric Framework

If the inter-relationships among adoption and market participation decisions are ignored in modeling, each decision will be evaluated as if it were non-correlated, an approach that may underestimate or overestimate the influences of various factors on each choice. In comparison, joint estimation can model the reality faced by decision-makers, who are often faced with alternatives that may be chosen simultaneously as complements, substitutes, or supplements. In such cases, it is assumed that farmers consider a bundle of possible technology-market options and choose the particular bundle that maximizes expected utility conditional on the decision. Thus, the adoption and market participation decision is inherently multivariate, and univariate modeling excludes useful economic information contained in interdependent and simultaneous decisions.

The multivariate probit (MVP) model, the specification of which is justified by the underlying economic theory, is implemented to simultaneously model the influence of the set of explanatory variables on crossbreeding adoption and milk and milk product market participation decisions. The MVP model recognizes the likely correlations between the unobserved and unmeasured factors (error terms) of the adoption decisions and market participation decisions. Decisions are also affected by unobservable household-specific factors that affect the choice of technology and markets, but are not easily observed or measurable, such as farmers' managerial ability, which may contribute to differences in adoption or participation. Another source of correlation may be complementarities (positive correlation) and substitutabilities (negative correlation) between different options (Belderbos et al. 2004). In contrast to multivariate probit models, univariate probit models ignore the potential correlation among unobserved disturbances in the adoption and market participation equations as well as relationships between adoption and milk and milk product market participation. Failure to capture unobserved factors and interrelationships among these decisions will lead to biased and inefficient estimates (Johnston 1984).

This section details the specification of the MVP used to fit the distribution of farmers' decisions about technology adoption and milk and milk product marketing participation. Consider the n^{th} farm household (n = 1, . . . , N) that is facing the dichotomous decision to participate or not in the available technology and market options. A crossbreeding technology adoption and market participation model is constructed following McFadden (1974), relying on random utility formulation. Let the i^{th} farmer's preferences for those options be summarized by the latent utilities index Y_{ik}^{*} for $(k = T, M, P)$ denoting the underlying latent propensities associated with crossbreeding adoption, milk marketing, and milk product marketing, respectively. The value of these latent utility indexes is determined by the observed individual characteristics and other transaction cost-related variables of the i^{th} producer (X_{ik}) with unknown weights (β_k) and other unobserved characteristics (u_{ik}). Assuming a linear relationship, the population regression function is:

$$Y_{ik}^{*} = X_{ik}'\beta_k + u_{ik} \ (k = T, M, P) \tag{1}$$

recalling that k indexes the observed choice of the crossbreeding technology and milk and milk product market participation.

Using the indicator function (Y_{ik}) for $(k = T, M, P)$, Equation (1) translates into the observed binary outcome equation for each choice under the following mapping from the latent variable to its observed realization:

$$Y_{ik} = \begin{cases} 0 & \text{if} \quad Y_{ik}^{*} \leq 0 \\ 1 & \text{if} \quad Y_{ik}^{*} > 0 \end{cases} \qquad (k = T, M, P) \tag{2}$$

In the multivariate model, in which the joint decisions to adopt crossbreeding and participate in milk and milk product marketing are possible, the error terms jointly follow a trivariate normal distribution (MVN_3) with zero conditional mean and variance normalized to unity (for reasons of parameter identifiability), where $(u_T, u_M, u_P) \sim MVN_3(0, \Omega)$ and the symmetric covariance matrix is given by:

$$\Omega = \begin{bmatrix} 1 & \rho_{TM} & \rho_{TP} \\ \rho_{MT} & 1 & \rho_{MP} \\ \rho_{PT} & \rho_{PM} & 1 \end{bmatrix} \tag{3}$$

Of particular interest are the off-diagonal elements in the covariance matrix, which represent the unobserved correlation between the stochastic components of crossbreeding and market participation. This assumption means that Equation (2) gives a MVP model that jointly represents decisions to adopt crossbreeding and market participation. This specification with non-zero off-diagonal elements allows for correlation across the error terms of several latent equations, which represent unobserved characteristics that affect choice of crossbreeding and milk and milk product markets.

4. Study Areas and Sampling

This study is based on data from a household survey conducted in the mixed crop-livestock farming system of three zones in the central highlands of Ethiopia – east, west, and north Shewa zones – studied by the Ethiopian Institute of Agricultural Research (EIAR) in 2006. Mixed crop-livestock farming is the dominant farming system in these areas, where the dairy cow is considered an important and integral part of the farming system. The three study areas are found within a radius of 100 km from the capital city of the country, Addis Ababa. Proximity to the capital and to the peri-urban areas around the study areas provides important market opportunities for farmers' agricultural products and by-products. The initial sample contains 500 randomly selected farm households. However, after removing inconsistent and non-systematically missing information, data from 481 farmers was used in our empirical estimation. A two-stage cluster random sampling technique was employed for selecting districts and respondents from each area. The sample households were randomly selected from the village rosters, which record all members of the villages.

5. Data and Descriptive Statistics

The database features detailed survey information on crop and livestock production, processing, and marketing, as well as detailed socio-economic characteristics of the farm households, behaviors, and key livestock variables such as supplementary feeds, veterinary services, training on livestock management, and herd size. In our data set, we include both technology adoption and participation as sellers in output markets. Market participation is defined according to dairy product marketing status. The milk marketing category is comprised of respondents who claim to be involved in selling fluid milk. The milk product marketing category consists of farm households who processed milk using home-based practices to produce butter and cheese for sale. Following the definition of Abdulai and Huffman (2005), we defined adopting households as those owning at least one crossbred cow, while non-adopting households owned only indigenous or local breeds.

Table 1 contains the empirical descriptions and descriptive statistics of the variables used in the estimation. The variables hypothesized to explain crossbreeding adoption and market participation are identified based on the theoretical framework and on past empirical studies on technology adoption and market participation. Because of the empirical challenges relating to the measurement of transaction costs, we followed Alene et al. (2008) and determined the transaction costs based on factors that explain or mitigate transaction costs. Accordingly, we used the following variables to control for heterogeneity among farm households in transaction costs: distance from the extension agent's office; distance from the main market; distance from milk collecting points; distance from main road; ownership of animals used for transportation; and membership in farmers' cooperatives or rotating credit/savings clubs. These variables represent differential transaction costs that stem from asymmetries in access to assets, information, services, and remunerative markets. For example, the average walking distance to the milk collecting points is 0.72 hour, but farmers participating in milk product marketing are located significantly farther away, while the distance is significantly shorter for farmers selling milk and adopting crossbreeding.

The table also reports various socio-economic characteristics such as wealth of the households, measured by farm size, herd size, and intensity of crop technology adoption and use of various complementary inputs. We also report a number of household characteristics used as additional controls. For instance, we believe that household members' regular travel to the nearest town and farmers' risk preference may affect technology adoption and market participation decisions. The former is controlled by including two dummy variables representing whether the household member is engaged in off-farm work and whether the older children attend secondary school.

With regard to the second control – risk preference – we note that livestock production is often sensitive to changing environmental stresses, inadequate feed production, limited market size, and product perishability. Despite that, *ex ante* risk-easing mechanisms, such as insurance markets, are not well developed for livestock production in developing countries. One concern is that farmers' technology adoption and market participation decisions are modified in response to the presence of these uncertain production environments. The nature and degree of this alteration is determined by the magnitude of the decision maker's preferences toward risk. Hence, we included questions[3] in the survey to elicit farmers' risk preferences.

The approach for eliciting farmers' risk preference was set up following Binswanger's (1980) experimental method. This approach, which can be conducted as a hypothetical or a real-payoffs situation, measures attitudes by observing the reactions of farmers to a set of actual gambles. In this survey, respondents were presented with lotteries of the form (q_{max}, q_{min}, p) that promised a monetary prize of q_{max} with probability p, or q_{min} with probability of 1-p. To avoid

[3] See Teklewold and Köhlin (2011) for the basic structure of the instrument used for measuring farmers' risk preference.

hypothetical bias and provide an incentive for the farmers to reveal their true preferences, our experiment included a real payoff. The lotteries represent different farming conditions with six different payoff levels for a given probability of bad or good outcome (such as harvesting). The sample farm households were allowed to choose from the different pay-off alternatives. Once the households selected one of the alternatives, they had a 50% probability of getting either the bad harvest or good harvest pay-offs. The experimental method consisted of offering farmers a set of alternatives representing different risk aversion classes (extreme, severe, intermediate, moderate, slight, and neutral) within which higher expected gains could be obtained only at the cost of higher variance, thus indicating a decline in risk aversion.

6. Results and Discussions

6.1. Conditional and Unconditional Adoption and Market Participation

The distribution of farm households for crossbreeding adoption and market participation is presented in Table 2. Of the 481 households considered in the analysis, about 2.4% neither adopted crossbreeding nor participated in milk or milk product marketing. Actually, these farmers are not producing milk at all. While nearly all households use at least one of the options, only 11% of households jointly use all three options. Fresh milk and milk product marketing is practiced by 62% and 57% of sample households, respectively. Whereas fresh milk marketing alone is practiced by 19% of the households, milk product marketing alone is practiced by 23% of the households. Interestingly, however, only 11% of the households jointly participated in fresh milk and milk product marketing. At the time of the survey, 227 farm households in the sample had adopted crossbreeding livestock technology (46% of the total sample). This adoption is observed jointly with fresh milk marketing (22%) or milk product marketing (13%) or both (11%). The results indicated that crossbreeding adoption is higher with fresh milk marketing than with milk product marketing.

While these empirical descriptive statistics on the joint and marginal probabilities provide interesting results, the sample unconditional and conditional probabilities also highlight possible dependence between technology adoption and market participation (Table 3). To mention some results, the unconditional probability of a household using crossbreeding is 46%. However, this probability of adoption is significantly increased to 53% conditional on participation in fresh milk marketing. Similarly, the conditional probability of a household participating in fresh milk marketing is significantly higher, at 71%, if farmers have adopted crossbreeding. Perhaps this is an indication of complementarity between crossbreeding and fresh milk marketing. However, adoption of crossbreeding does not appear to motivate farmers to market home-processed milk products. Further, the probability of fresh milk marketing is reduced by more than 40% when households participated in milk product marketing. Equally, the probability of a household participating in milk product marketing conditional on fresh milk market participation is reduced to 34%. The results indicate a significant substitution effect between milk and milk product marketing.

6.2. Regression Results

The MVP model[4] is estimated using the maximum likelihood method on various socio-economic characteristics of the farm households (Table 4). We also estimated alternative specifications including non-linear and interaction terms to check the robustness of the result (Table 5). The estimated models fit the data reasonably well – the Wald test of the hypothesis that all of the regression coefficients are jointly equal to zero is rejected, indicating that at least one of the regression coefficients in the model is statistically different from zero. For comparison, single equation estimates are included in Table 4. Note the improvement in fit by using the multivariate model over single-equation estimates. Note also the differences in the size and in some cases the significance of the coefficients between the two models. The individual and joint statistical significance of the correlation coefficients from the trivariate probit is supporting evidence for correlated latent responses among choices of technology adoption and different types of market participation. The likelihood ratio test allows us to reject the null hypothesis that the covariance of the error terms across equations are not correlated [$\chi^2(3) = 7.68$, p=0.0531). Thus, studies that consider technology adoption and market participation in isolation could lose important implications about cross-equation correlations, potentially yielding erroneous inferences.

As expected, a clear pattern is observed in the estimated correlation coefficients presented in Table 4. The estimated correlation coefficients are statistically significant in two of the three pair cases. The results collaborate the conditional and unconditional adoption probabilities reported in Table 3. The perceived interaction between technology adoption and market participation decisions and its potential effects on the farmer's net return distribution is accounted for in the MVP approach. The correlation coefficients between crossbreeding adoption

[4] The results are obtained with a Stata routine following Cappellari and Jenkins (2003) and are based on 21 random draws.

and participation in milk marketing and crossbreeding and participation in milk product marketing are positive and negative, respectively. The coefficient is statistically significant at the 5% level in the former case, with an absolute correlation coefficient of 38%. Moreover, this complementarity correlation suggests that the decision to adopt crossbreeding may make participation in fresh milk marketing more likely, and vice versa. It could be argued that farmers who adopt crossbreeding tend to be highly productive so that, behaviorally, they are also more likely to participate in a high return market (such as fresh milk marketing). On the other hand, the negative correlation coefficient between participation in fresh milk marketing and milk product marketing is intuitive and suggests strong substitutability between these markets. Here, unobservable factors that increase the probability of participating in fresh milk marketing actually reduce the probability of milk product market participation.

The MVP results suggest that there is heterogeneity with regard to factors influencing the choice to adopt crossbreeding and to participate in milk and milk product marketing.[5] The hypothesis that transaction costs affect the probability of adoption of crossbreeding and market participation is confirmed. The results indicate that, among the factors that influence transaction costs, distance from the main market and distance from milk collecting points seem to be important determinants. The distance to the main market affects the spatial transaction costs to trade in this particular market, as well as the opportunity to gather information and communicate during processes of innovation diffusion and market participation. Variation in spatial distance from the main market is expected to capture heterogeneity in farmers' transaction costs in accessing information about market supply and demand, as well as affecting the availability of technologies or other necessary inputs that enhance their productivity. The implication of the negative coefficient is that an increase in the distance to the main market is associated with higher transaction costs as well as constraints that hinder the flow of information; these, in turn, reduce the likelihood of crossbreeding adoption and fresh milk market participation. Hence, this variable could capture the role of market transaction costs as a possible cause for technology adoption and market participation.

[5] It is likely that the parameter estimates in the model may suffer from endogeneity bias because some of the variables may be correlated with individual- and household-level unobserved heterogeneity (for example, missing market, intrinsic motivation and ability). To address this issue and limit the possible endogeneity bias in a cross-sectional data setting, a two-stage instrumental variable regression is needed. However, we weren't able to find better instruments that satisfy the admissibility criteria. Therefore, we would like to note that the results should be taken with caution.

As expected, the distance from the milk collecting points has different effects on the probability of participation in fresh milk and milk product marketing. The further the milk collecting station is from home, the less likely is fresh milk marketing, and the more likely is milk product marketing. The result confirms the argument that, in the presence of transaction costs in milk marketing and constraints arising from the perishable nature of milk, farmers may move into home-based milk processing using traditional technologies to produce extended shelf life dairy products (butter and cheese). These milk products may relax the temporal and spatial market constraints associated with milk marketing. Whereas fluid milk is usually marketed nearby in a very short production-to-marketing window, processed milk products may withstand lengthy transportation and can wait for a while after production.

However, a non-parametric regression of distance to collection point on the decision to adopt crossbreeding and participate in fresh milk and milk product marketing shows that the relationship between market participation and distance is non-linear (Figure 2). This result is confirmed in the MVP, although the included squared term is significant only in the fresh milk market equations (Table 5). Here, we observe a U-shaped relationship in which the nearest and most distant farmers are more likely to participate in fresh milk marketing. Wealthier households (measured by Tropical Livestock Units) are more likely to engage in both fresh milk and milk product marketing. However, including the square of the wealth term confirms the presence of an inverted U-shaped relationship between wealth and fresh milk market participation. Results are shown in the sixth and seventh columns of Table 5. When we include the square of the wealth term, the linear term of the distance variable becomes negligible. We also regress non-parametrically the distance to collection point on wealth. The result is presented in Figure 3. Here, we observe an inverse relationship between wealth and distance to collection point, in which the poorest travel the longest distance. Because of this relationship, we introduce an interaction term between wealth and distance to collection point in the last three columns of Table 5. The positive sign of the interaction term in Columns 8 and 10 of Table 5 indicates that, as distance increases, it becomes more attractive for wealthier households who can afford public transportation to visit distant markets, hence making them more likely to adopt crossbreeding and less likely to participate in milk product marketing.

Ownership of transport animals has a significant effect on fresh milk and milk product market participation and adoption of crossbreeding. The effect is positive in fresh milk marketing and negative in milk product marketing. This suggests that, because ownership of pack animals increases the likelihood of fresh milk marketing by reducing the transaction costs, farmers who own pack animals are less involved in milk product marketing. The effect of pack animals on crossbreeding adoption is negative. This is perhaps because transport animals increase market participation by facilitating product transport more than they reduce transport cost to access information and productive assets.

Membership in rotating savings/credit clubs has a positive and significant effect on fresh milk market participation. The need for immediate cash for contribution to the group saving association and the credit obtained from the association, which relaxes cash constraints for transport costs, may provide an opportunity for farmers to participate in fresh milk marketing. It should be noted, however, that, while membership in a credit/savings club may facilitate fresh milk marketing, participation in fresh milk marketing may well make membership in a credit/savings club worthwhile.

Cooperatives provide another membership opportunity. Cooperatives, by providing bulking and bargaining services, increase outlet market access and help farmers avoid the hazards of being encumbered with a perishable product (Holloway et al. 2000). However, probably because cooperative members are closer than non-members to milk collection points, membership in cooperatives does not have a separate effect on market participation.

Farmers' access to improved livestock feeds (concentrated feeds) and veterinary services are important complementary inputs to integrating modern livestock production practices in the crop-livestock system. As with most innovations that involve a package of complementary inputs (Carlson et al. 1993), the same constraints that limit the use of these inputs also limit adoption of crossbred cow technology. The coefficients of these variables are both positive and statistically significant. The result is in agreement with the discussion by Abdulai and Huffman (2005); they argue that adoption of crossbred cows is not likely without these supporting technological inputs because increased productivity of the livestock system based on crossbreeding is not intrinsic to the modified germplasm, but is rather a function of the availability of complementary inputs.

The other most basic complementary input for new technologies is human capital (Carlson et al. 1993). The positive and significant effect of technical training on livestock production and management (including training on adoption of crossbreeding technology) is a clear indication of the importance of subject-specific skills for the critical evaluation of innovations. Technical training of this nature is considered a component of human capital, defined by Carlson et al. (1993) as disembodied technological change taking the form of knowledge about improved methods of production. With subject-oriented skills, as is the case here, allocative ability becomes increasingly advanced (Schultz 1975; Carlson et al. 1993). As a result, farmers with training can realize the advantages of new technologies and adjust their production decisions to reflect new opportunities for productivity by incorporating innovations into the production process. As expected, the coefficient of extension is positive and significant in the crossbreeding adoption equation, showing the important role of extension services in technology adoption decisions. Extension has a positive impact on milk product market participation. However, extension has a negative effect on fresh milk market participation.

As expected, higher levels of risk aversion have a negative effect on the propensity to adopt crossbreeding livestock technology. Among the sample households, about 53% of non-adopters and 45% of adopters of livestock technology fell in the intermediate to extreme risk aversion categories (Table 1). This result is similar to those of Yesuf and Bluffstone (2009) and Teklewold and Kohlin (2011), who found that about 50% of farm households in the Ethiopian highlands fell in the same risk-aversion categories. Understandably, success in keeping crossbred cows is likely to be affected by several random variables that bring uncertainty to the yield and even risk of technology failure; these random variables include uncertainty about marketing livestock products and the possible death of cows, which is a specific risk due to the need for intensive and costly management practices (Abdulai and Huffman 2005). Therefore, farmers' risk preferences related to this decision process interacts with uncertainty about the technology and the effect it produces. Consistent with Baerenklau (2005) and Carlson et al. (1993), risk-averse farmers who do not invest in livestock technology may expect the worst consequences, which makes it less likely that they will adopt new agricultural technologies. Risk-averse farmers as decision-makers endeavor to stay away from having crossbred cows, a strategy that would be expected to produce a relatively high variance of farm income, and to migrate instead toward strategies of the status quo with relatively low variance, possibly at the cost of some reduction in expected farm income.

The presence of children attending secondary school has a significantly negative effect on milk product market participation and a positive but non-significant effect on fresh milk market participation and crossbreeding adoption. The result is consistent with Fafchamps and Hill (2005), who found that attending secondary school, which is often located in rural market towns, could motivate trips to the market. In this case, because children attending school can take the milk to the market town when they travel to school, the marginal cost of milk market participation is zero. Hence, farmers are less likely to engage in low-return marketing of milk products.

The effect of off-farm work participation on crossbreeding adoption and fresh milk marketing is positive and significant at the 1% and 10% significance levels, respectively, while the effect of off-farm work on milk product marketing is negative and significant at the 5%

significance level. Some possible explanations of this finding are that, beyond its role in relaxing liquidity constraints to finance investment in dairy technologies, off-farm work provides an opportunity for farm households to stabilize household income and thus reduces their aversion to the risk associated with crossbreeding adoption and fresh milk marketing. It is expected that increased reliance on off-farm work affects the allocation of family labor, which influences milk processing and thus has a negative effect on milk product marketing. Off-farm work, often available in towns, allows farmers to visit the market more frequently, thus increasing access to information and market opportunities and hence encouraging technology adoption and milk marketing.

An additional insight from the MVP is that, while male-headed households have a greater probability of crossbreeding adoption, female-headed households have a greater likelihood of participation in milk product marketing. Finally, as the adoption of crop technology increases, the probability of participation declines in both markets.

7. Conclusions and Policy Implications

Technology adoption and market participation are highly topical concerns in all areas of economics, including agriculture. Our research contributes to the existing literature by examining the adoption of technology and different types of market participation jointly, rather than the adoption of a specific technology or market participation alone, which has been the focus of many studies. We estimated a MVP model for allowing correlations across technology adoption and market participation equations in the model specification. The estimated correlation coefficients between crossbreeding adoption and fresh milk market participation are positive, while the correlation coefficients between crossbreeding adoption and milk product market participation (which has lower returns than fresh milk marketing) are negative. These results are statistically significant and indicate that single-equation estimation loses important cross-equation correlation effects. There is good reason to assume that farmers make these decisions jointly and that they are more likely to engage in both crossbreeding technology and fresh milk marketing when these activities complement each other. When technologies and markets are complements, the adoption of a technology will, in turn, influence farmers' participation in the market.

We found evidence that high transaction costs, such as distance to markets and milk collection points, discourage entry into the high-return market relative to entry into the low-return market. By discouraging entry into the high-return market, transaction costs also discourage the complementary activity of adoption of productivity-enhancing technology. We also found that certain household characteristics encouraged fresh milk marketing; these include secondary school attendance, which allows children to deliver milk when they go into town for school, and membership in credit/savings clubs, which relaxes liquidity constraints. Off-farm work also encourages the higher-return fresh milk marketing activity, possibly by increasing the amount of time spent in town, relaxing liquidity constraints, and/or reducing risk aversion through income diversification.

We also identified some factors that promote crossbreeding technology adoption, including access to improved livestock feeds (concentrated feeds) and veterinary services, as well as technical training in livestock management.

Because the current economic environment requires movement from traditional farming methods toward a market-oriented production system, the findings of this study suggest that policy options should jointly encourage technology adoption and participation in profitable market opportunities. Indeed, the results provide evidence that services such as nearby milk collection points are important in mitigating transaction costs and positively influencing milk market transactions.

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Tables and Figures

Table 1. Descriptive Statistics and Definition of Variables Used in the Analysis

Variables	Crossbreeding		Milk marketing		Milk product marketing	
	non-adopters	adopters	non-participants	participants	non-participants	participants
Characteristics of transactions:						
Distance from DA's office, hrs	0.49	0.48	0.49	0.48	0.50	0.47
	(0.45)	(0.44)	(0.45)	(0.44)	(0.42)	(0.46)
Distance from market, hrs	0.71	0.64	0.71	0.65	0.63	0.71
	(0.48)	(0.47)	(0.49)	(0.47)	(0.48)	(0.47)
Distance from milk collecting points, hrs	0.82	0.61	1.20	0.42	0.43	0.94
	(0.43)	(0.49)	(0.35)	(0.20)	(0.27)	(0.46)
Distance from main roads, hrs	0.17	0.23	0.26	0.16	0.20	0.19
	(0.29)	(0.39)	(0.49)	(0.19)	(0.28)	(0.38)
1=Own pack animals	0.74	0.30	0.59	0.50	0.57	0.52
Membership:						
1=farmers' cooperative	0.08	0.21	0.11	0.16	0.20	0.09
1=rotating credit/saving club	0.42	0.47	0.34	0.51	0.50	0.40
Complementary inputs:						
1= veterinary services	0.08	0.72	0.27	0.44	0.46	0.31
1=concentrated feeding	0.07	0.76	0.25	0.47	0.49	0.31
1=training on livestock management	0.05	0.30	0.16	0.17	0.17	0.16
1=credit use	0.65	0.65	0.70	0.62	0.56	0.72
Extension contact (days/month)	2.24	3.76	2.48	3.23	3.15	2.82
Characteristics of farmer:						
1= gender of the head is male	0.86	0.91	0.87	0.89	0.94	0.84
Age of the head, yrs	45.75	46.59	44.79	46.97	45.43	46.67
	(12.94)	(12.86)	(13.30)	(12.59)	(12.65)	(13.08)
Years of education of the head	3.30	4.99	3.65	4.34	5.03	3.36
	(3.72)	(4.35)	(3.93)	(4.20)	(4.33)	(3.78)
Household size	6.06	6.56	6.03	6.46	6.27	6.31
	(2.20)	(2.28)	(2.09)	(2.33)	(2.31)	(2.20)
1=household engaged in off-farm work	0.36	0.47	0.44	0.39	0.42	0.40
1=child attending secondary school	0.71	0.85	0.71	0.81	0.82	0.74
Farmer's risk preference (Rank)						
1=Risk-preferring to neutral	0.17	0.21	0.16	0.20	0.18	0.19
2=Neutral to slight aversion	0.10	0.15	0.15	0.11	0.10	0.14
3=Moderate aversion	0.20	0.19	0.22	0.18	0.20	0.19
4=Intermediate aversion	0.18	0.19	0.17	0.19	0.17	0.19
5=Severe aversion	0.12	0.08	0.12	0.09	0.10	0.10
6=Extremely risk averse	0.23	0.18	0.18	0.23	0.24	0.19
Cultivated land area, ha	2.15	2.54	2.42	2.28	2.04	2.55
	(1.53)	(1.88)	(1.47)	(1.84)	(1.62)	(1.74)
Crop technology (share of area with improved seeds)	0.61	0.60	0.55	0.64	0.73	0.51
	(0.38)	(0.40)	(0.37)	(0.39)	(0.37)	(0.38)
Herd size (TLU)	5.80	7.82	5.47	7.51	6.59	6.83
	(3.02)	(4.86)	(3.45)	(4.28)	(4.07)	(4.13)
Location dummies:						
1=North Shewa zone	0.36	0.49	0.51	0.37	0.32	0.50
1=West Shewa zone	0.18	0.12	0.08	0.20	0.26	0.07
1=East Shewa zone	0.32	0.25	0.28	0.29	0.32	0.26
Number of observations	266	227	189	304	212	281

* Numbers in parentheses are standard deviations.

Table 2. Summary of Sample Statistics of Participation in Crossbreeding Adoption, Milk and Milk Product Marketing

Participating in:	Joint probability	Marginal		
		Cross-breeding	Milk marketing	Milk product marketing
Milk marketing only	18.5	-	18.5	-
Milk product marketing only	22.5	-	-	22.5
Milk and milk product marketing	10.5	-	10.5	10.5
Milk marketing with crossbreeding	22.1	22.1	22.1	-
Milk product marketing with crossbreeding	13.4	13.4	-	13.4
Milk and milk product marketing with crossbreeding	10.5	10.5	10.5	10.5
None	2.4	-	-	-
Total	100.0	46.0	61.7	57.0

Table 3. Sample Conditional and Unconditional Participation Probabilities

	Crossbreeding (T)	Milk marketing (M)	Milk product marketing (P)
$P(Y_k = 1)$	46.0	61.7	57.0
$P(Y_k = 1 \mid Y_T = 1)$	1.0	71.0***	52.0
$P(Y_k = 1 \mid Y_M = 1)$	53.0**	1.0	34.2***
$P(Y_k = 1 \mid Y_P = 1)$	42.0	37.0***	1.0
$P(Y_k = 1 \mid Y_T = 1, Y_M = 1)$	1.0	1.0	32.3***
$P(Y_k = 1 \mid Y_T = 1, Y_P = 1)$	1.0	44.1***	1.0
$P(Y_k = 1 \mid Y_M = 1, Y_P = 1)$	50.2	1.0	1.0

Y_k is a binary variable representing the participation status with respect to choice k (k = crossbreeding adoption, milk marketing and milk product marketing).

*, ** and *** indicate statistically significant difference at 10, 5 and 1% respectively. The comparison is between unconditional probability and conditional probabilities in each practice.

Table 4. Estimation Results for Technology Adoption and Market Participation

Variabels	Multivariate probit			Univariate probit		
	Cross-breeding	Milk marketing	Milk product marketing	Crossbreeding	Milk marketing	Milk product marketing
Log (distance from DA's office)	-0.089	0.120	-0.133**	-0.084	0.135	-0.131**
	(0.08)	(0.14)	(0.07)	(0.08)	(0.15)	(0.07)
Log (distance from market)	-0.228**	-0.525***	-0.027	-0.227***	-0.444**	-0.063
	(0.10)	(0.20)	(0.12)	(0.10)	(0.20)	(0.11)
Log (distance from main road)	0.751	-4.025	-0.829	0.709	-5.738*	-0.791
	(1.07)	(3.19)	(1.15)	(1.06)	(3.21)	(1.15)
Log (distance from milk collecting point)	-0.060	-8.573***	4.303***	-0.071	-8.545***	4.472***
	(0.15)	(0.84)	(0.58)	(0.15)	(0.78)	(0.53)
Log (TLU)	0.054	1.538***	0.496**	0.045	1.605***	0.505**
	(0.24)	(0.47)	(0.25)	(0.24)	(0.51)	(0.26)
Own pack animals	-0.754***	0.967***	-2.399***	-0.772***	0.954***	-2.465***
	(0.22)	(0.36)	(0.39)	(0.23)	(0.39)	(0.38)
Farmers' cooperative	-0.477	1.360	0.060	-0.458	2.561	0.012
	(0.67)	(1.96)	(0.58)	(0.67)	(2.07)	(0.58)
Rotating credit/saving club	-0.129	0.656*	0.341	-0.122	0.639	0.339
	(0.21)	(0.39)	(0.22)	(0.21)	(0.43)	(0.22)
Veterinary services	1.330***	-0.490	-0.503*	1.324***	-0.475	-0.449
	(0.22)	(0.45)	(0.30)	(0.22)	(0.46)	(0.28)
Concentrated feed	1.828***	0.222	0.216	1.818***	0.405	0.156
	(0.25)	(0.46)	(0.31)	(0.25)	(0.45)	(0.30)
Training	0.822***	-0.465	0.401	0.822***	-0.674	0.396
	(0.32)	(0.47)	(0.28)	(0.32)	(0.50)	(0.28)
Credit	0.086	-0.377	0.468**	0.074	-0.356	0.520**
	(0.23)	(0.34)	(0.23)	(0.23)	(0.37)	(0.22)
Extension	0.124*	-0.864***	0.479***	0.114*	-0.981***	0.503***
	(0.07)	(0.23)	(0.13)	(0.07)	(0.16)	(0.14)
Risk preference	-0.092*	0.107	-0.072	-0.093*	0.060	-0.060
	(0.06)	(0.10)	(0.05)	(0.06)	(0.10)	(0.05)
Secondary school	0.330	0.452	-0.487**	0.321	0.465	-0.525**
	(0.24)	(0.45)	(0.23)	(0.25)	(0.47)	(0.24)
Off-farm work	0.483***	0.675*	-0.505**	0.483***	0.719**	-0.561***
	(0.19)	(0.40)	(0.21)	(0.19)	(0.43)	(0.22)
Male household head	0.829***	0.305	-0.993***	0.817***	0.351	-1.012***
	(0.28)	(0.50)	(0.30)	(0.28)	(0.50)	(0.30)
Log (age of the head)	-0.112	0.377	-0.589	-0.074	0.376	-0.563
	(0.40)	(0.73)	(0.39)	(0.42)	(0.72)	(0.40)
Log (years of education)	-0.128	0.115	-0.120	-0.119	0.115	-0.119
	(0.13)	(0.21)	(0.14)	(0.14)	(0.22)	(0.14)
Log (householdsize)	-0.161	-0.701	0.358	-0.160	-0.765	0.389
	(0.27)	(0.59)	(0.27)	(0.27)	(0.55)	(0.27)
Log (cultivated land)	0.158	-0.086	-0.312**	0.154	-0.133	-0.302*
	(0.15)	(0.30)	(0.17)	(0.15)	(0.32)	(0.18)
Crop technology	0.300	-1.310**	-0.594**	0.289	-1.330***	-0.567**
	(0.30)	(0.59)	(0.30)	(0.30)	(0.56)	(0.31)
Constant	-2.495	-4.637	6.155***	-2.528	-4.146*	6.014***
	(1.66)	(2.94)	(1.62)	(1.68)	(3.09)	(1.66)
Correlation coefficients: $\rho_{TM} = 0.378^{**}$ (0.196); $\rho_{TP} = -0.083$ (0.176); $\rho_{MP} = -0.596^{**}$ (0.275). LR test of $\rho_{TM} = \rho_{TP} = \rho_{MP} = 0$: $\chi^2(3)$ = 7.68 and $p > \chi^2(3)$ = 0.053. Wald χ^2 = 494.72***. Number of observations =481				N=481 Wald χ^2 (24) = 179.23***	N=481 Wald χ^2 (24) = 152.32***	N=481 Wald χ^2 (24) = 135.35***

* Numbers in parentheses are robust standard errors; *** denotes significant at 0.01, ** significant at 0.05 and* significant at 0.1. Location controls are included but not shown here.

Table 5. Alternative Specifications for Technology Adoption and Market Participation Using MVP

Variables	Model-1			Model-2			Model-3		
	Cross-breeding	Fresh milk	Milk product	Cross-breeding	Fresh milk	Milk product	Cross-breeding	Fresh milk	Milk product
Log (distance from DA's office)	-0.086	0.093	-0.131*	-0.085	0.102	-0.131*	-0.095	0.129	-0.135**
	(0.076)	(0.154)	(0.068)	(0.076)	(0.157)	(0.068)	(0.076)	(0.167)	(0.069)
Log (distance from market)	-0.225**	-0.485***	-0.042	-0.225**	-0.392*	-0.034	-0.219**	-0.425**	-0.011
	(0.095)	(0.175)	(0.112)	(0.096)	(0.208)	(0.116)	(0.097)	(0.207)	(0.117)
Log (distance from main road)	0.683	-1.121	-0.776	0.680	-0.799	-0.720	0.504	-1.847	-0.682
	(1.043)	(5.041)	(1.183)	(1.039)	(4.606)	(1.174)	(1.065)	(4.697)	(1.156)
Log (distance from milk collecting points)	-0.195	-6.777***	4.009***	-0.259	-2.939	4.298***	-0.630	-3.314*	6.922***
	(0.217)	(0.715)	(0.656)	(0.671)	(1.949)	(0.755)	(0.756)	(1.924)	(1.054)
Square of log (distance from milk collection)	-0.125	5.927***	-0.271	-0.119	5.926***	-0.336	-0.047	6.002***	-0.793
	(0.167)	(1.455)	(0.431)	(0.179)	(1.424)	(0.473)	(0.193)	(1.376)	(0.527)
Log (TLU)	0.040	1.488***	0.461*	0.051	1.243**	0.293	-2.419**	1.445	4.976***
	(0.242)	(0.475)	(0.259)	(0.274)	(0.558)	(0.451)	(1.224)	(2.039)	(1.246)
Square of log(TLU)				0.035	-1.999*	-0.220	0.259	-1.821*	-1.78***
				(0.343)	(1.048)	(0.452)	(0.396)	(1.060)	(0.613)
Log(TLU)*Log(distance from milk collection)							0.715**	-0.059	-1.51***
							(0.335)	(0.585)	(0.386)
Own pack animals	-0.778***	1.018***	-2.465***	-0.77***	1.149***	-2.46***	-0.72***	1.035**	-2.67***
	(0.221)	(0.382)	(0.406)	(0.224)	(0.440)	(0.409)	(0.225)	(0.427)	(0.423)
Farmers' cooperative	-0.450	-0.653	-0.006	-0.450	-0.821	-0.020	-0.297	-0.227	-0.134
	(0.654)	(3.549)	(0.582)	(0.654)	(3.189)	(0.580)	(0.669)	(3.238)	(0.594)
Rotating credit/saving club	-0.132	0.712*	0.364	-0.132	0.622	0.353	-0.142	0.629	0.281
	(0.209)	(0.380)	(0.223)	(0.210)	(0.385)	(0.224)	(0.215)	(0.391)	(0.234)
Veterinary services	1.335***	-0.531	-0.515*	1.333***	-0.688	-0.519*	1.362***	-0.671	-0.552*
	(0.219)	(0.491)	(0.289)	(0.216)	(0.507)	(0.292)	(0.223)	(0.519)	(0.295)
Concentrated feed	1.832***	0.161	0.225	1.829***	0.342	0.227	1.833***	0.360	0.311
	(0.250)	(0.514)	(0.296)	(0.250)	(0.523)	(0.298)	(0.251)	(0.555)	(0.301)
Training	0.807**	-0.510	0.424	0.812**	-0.502	0.428	0.801**	-0.487	0.494*
	(0.323)	(0.518)	(0.281)	(0.326)	(0.561)	(0.280)	(0.323)	(0.562)	(0.278)
Credit	0.077	-0.373	0.502**	0.077	-0.225	0.499**	0.110	-0.222	0.442**
	(0.224)	(0.351)	(0.221)	(0.224)	(0.372)	(0.221)	(0.226)	(0.380)	(0.224)
Extension	0.153*	-0.880***	0.558***	0.154*	-0.85***	0.543***	0.109	-0.91***	0.569***
	(0.079)	(0.251)	(0.188)	(0.079)	(0.267)	(0.195)	(0.089)	(0.260)	(0.187)
Risk preference	-0.094*	0.105	-0.072	-0.095*	0.116	-0.072	-0.082	0.109	-0.077
	(0.055)	(0.095)	(0.054)	(0.054)	(0.098)	(0.054)	(0.054)	(0.096)	(0.056)
Secondary school	0.341	0.403	-0.490**	0.339	0.330	-0.478**	0.325	0.364	-0.489**
	(0.240)	(0.474)	(0.233)	(0.238)	(0.468)	(0.236)	(0.243)	(0.481)	(0.246)
Off-farm work	0.481**	0.618	-0.523**	0.484**	0.662	-0.534**	0.421**	0.662	-0.505**
	(0.193)	(0.425)	(0.211)	(0.191)	(0.429)	(0.213)	(0.201)	(0.429)	(0.217)
Male household head	0.843***	0.189	-0.988***	0.841***	0.254	-0.99***	0.835***	0.251	-1.03***
	(0.283)	(0.530)	(0.307)	(0.284)	(0.531)	(0.310)	(0.280)	(0.557)	(0.332)
Log (age of the head)	-0.128	0.163	-0.593	-0.129	0.326	-0.610	-0.217	0.247	-0.575
	(0.392)	(0.783)	(0.386)	(0.394)	(0.761)	(0.388)	(0.391)	(0.766)	(0.386)
Log (years of education)	-0.130	0.099	-0.125	-0.131	0.091	-0.132	-0.147	0.089	-0.154
	(0.132)	(0.217)	(0.133)	(0.132)	(0.228)	(0.131)	(0.130)	(0.229)	(0.134)
Log (household size)	-0.185	-0.594	0.376	-0.180	-0.641	0.381	-0.173	-0.633	0.333
	(0.267)	(0.619)	(0.269)	(0.265)	(0.629)	(0.271)	(0.268)	(0.636)	(0.284)
Log (cultivated land)	0.163	-0.033	-0.321*	0.162	-0.050	-0.334**	0.119	-0.100	-0.352**
	(0.154)	(0.396)	(0.169)	(0.154)	(0.407)	(0.166)	(0.160)	(0.412)	(0.171)
Crop technology	0.325	-1.288**	-0.581*	0.319	-1.122*	-0.601**	0.276	-1.231**	-0.635*
	(0.295)	(0.628)	(0.311)	(0.298)	(0.620)	(0.305)	(0.305)	(0.620)	(0.325)
Constant	0.755***	0.751*	0.214	0.750**	0.796*	0.217	0.842***	0.841*	0.213
	(0.290)	(0.450)	(0.253)	(0.292)	(0.469)	(0.253)	(0.288)	(0.473)	(0.264)
Correlation coefficients:	ρ_{TM} = 0.439** (0.217)			ρ_{TM} = 0.392** (0.216)			ρ_{TM} = 0.459** (0.235)		
	ρ_{TP} = -0.091 (0.179)			ρ_{TP} = -0.095 (0.177)			ρ_{TP} = -0.025 (0.204);		
	ρ_{MP} = -0.509** (0.226)			ρ_{MP} = -0.549** (0.252)			ρ_{MP} = -0.383* (0.223)		
LR test of $\rho_{TM} = \rho_{TP} = \rho_{MP} = 0$	$\chi^2(3)$ = 6.61 and p=0.085			$\chi^2(3)$ = 6.60 and p=0.086			$\chi^2(3)$ = 4.67and p=0.198		
Wald χ^2	527.80			561.20			564.83		

* Numbers in parentheses are robust standard errors; *** denotes significant at 0.01, ** significant at 0.05 and* significant at 0.1. Location controls are included but not shown here.

Figure 1. Cumulative Distribution for the Return of Fresh Milk and Milk Product Market Participation

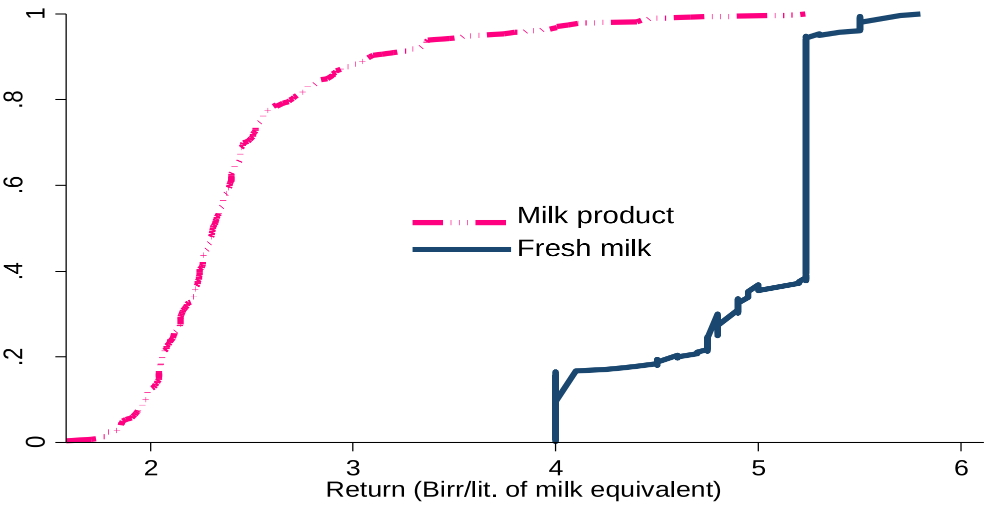

Figure 2. Non-parametric Estimation of Effect of Distance Travelled to Milk Collecting Points on the Probability of Crossbreeding Adoption and Market Participation (Kernel Regression with 95% Confidence Intervals)

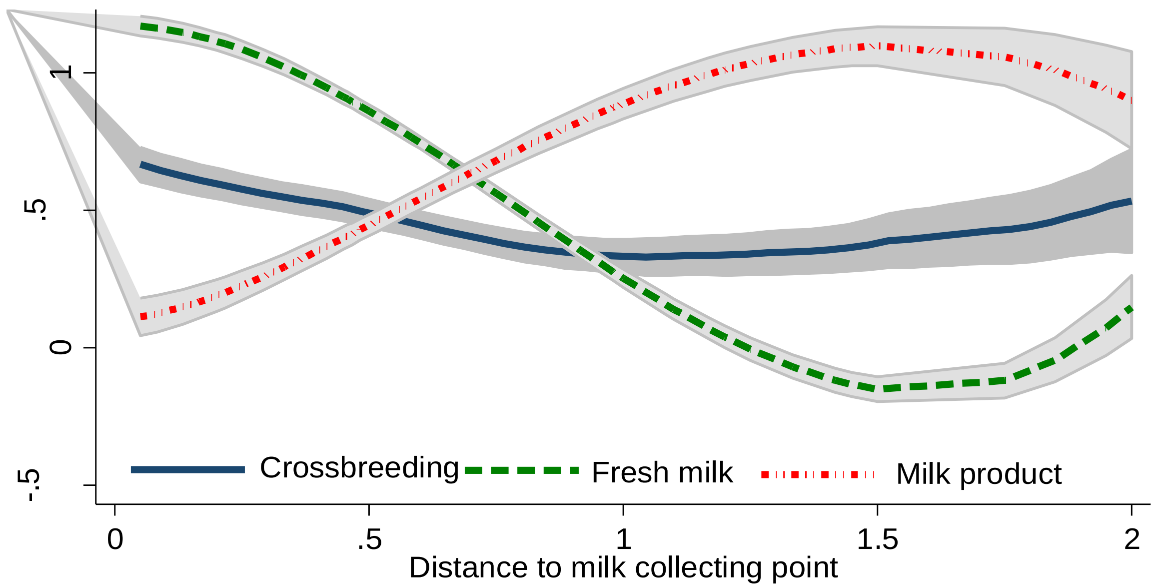

Figure 3. Non-parametric Estimation of Effect of Wealth (TLU) on the Distance Travelled to Milk Collecting Points (Kernel Regression with 95% Confidence Intervals)