Determinants of Adoption of Dairy Cattle Technology in the Kenyan Highlands: A Spatial and Dynamic Approach

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Abstract

Adoption of high grade cows by smallholders is driven by the objective of increased milk production, for both home consumption and sale. Smallholders are believed to have a comparative advantage in rearing grade cows, but constraints to adoption are numerous: the cost of a grade cow is relatively high, and the dairy enterprise is risky. Risks include animal diseases and lack of reliable marketing outlets. Marketing risks are a common preoccupation for smallholders but it is particularly relevant for milk, which is bulky, highly perishable, and sold daily. Using a dynamic and spatial framework. this study tests the hypothesis that access to credit facilitates adoption. GIS-derived distances are computed and introduced in a duration model in order to control for market access. Time is expected to play a key role in adoption and two time dimensions are introduced: an idiosyncratic time describing the conditions faced by the household at the beginning of the spell and historical time accounting for the changes in the external conditions. Results show that access to credit cannot be excluded as a reason for delaying adoption of grade cows. Policy changes over time are also found to play a role in the adoption process, as the reduced availability of reliable market channels and veterinary services after liberalisation in 1992 are shown to have shifted down the adoption function.

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1. Smallholder dairy farming in Kenya

Smallholder dairying has a long history in Kenya, dating back to the beginning of the century when the British introduced the first dairy cows in the so-called "White Highlands". Today, dairying offers good opportunities for improving the standard of living of smallholders through the sale of milk and higher milk consumption. Local communities benefit indirectly, since dairying provides employment opportunities on the farms and for livestock-related activities (feed collection and marketing as well as veterinary and other services).

The main reason for keeping dairy cows (or high grade cows, referring to the improved exotic breeds and their crosses) compared to local breeds cows is their higher milk potential, milk that is both consumed on farm and sold. Farmers with grade cows are usually market-oriented since the higher production levels enable them to sell the milk surplus. Yet, the entry cost into dairying and risks are high: risk of animal diseases (essentially tick-borne diseases and pneumonia) and lack of reliable marketing channels. The last factor is crucial, recalling that milk is a bulky and highly perishable product that cannot be stored without appropriate cooling systems. On the other hand, smallholders are believed to have a comparative advantage in rearing dairy cows because of the high labour requirements of the activity and the great care that dairy cows need to reach their genetic potential.

In this paper, the hypothesis that credit plays a role in the adoption in tested in a dynamic and spatial framework that controls for the other factors. Adopters are defined as households with at least one cross-bred or dairy animal at the time of the survey. Non-adopters are agricultural households with only local animals or no animals at all. There are several ways to meet the entry cost into dairying, of which one is through access to credit. Previous studies have shown the important role of credit in dairy farming in East Africa (Freeman et al.), but without focusing on the role of credit in the adoption of dairy cattle. The household decision to adopt the dairy cattle technology at time *t*, given that he has not yet adopted, can be seen as the result of two time processes, an idiosyncratic time describing the own history of the household and a "historical" time describing external conditions (Carletto et al.). The household decision to adopt after a certain length of time after establishment can then be analysed using a duration model that takes into account the two types of factors, at the household level and the external conditions.

The remainder of the paper is organised as follows. Section 2 exposes the theoretical background and gives the hypothesis of the analysis. In section 3, the survey design and data collection are presented. Section 4 presents the estimation of a formal duration model of adoption. Section 5 concludes.

2. The determinants of dairy cattle technology adoption over time

For many smallholders, adoption of dairy cattle is a promising way to increase their income. Yet, the entry cost and production risks are high. Farmers in areas highly infected with tick-borne diseases may consider dairying a risky enterprise, even if prevention measures and treatments are available. Further, marketing is an important problem in some areas since the beginning of the 90s when delayed milk payments by the Kenyan Cooperatives Creameries started (the "buyer of last resort" in the milk market until 1992) and after the 1992 liberalisation. Dairy cooperatives have been created to organise the milk collection and to facilitate the marketing of the milk. The need for an organisation to collect and market smallholders' milk can be referred to the concept of network externalities, whereby potential adopters care about how many individuals adopt, where they are located and when they adopt since a single adopter may find it difficult to market alone its new production.

Some cooperatives offer other services, like artificial insemination services and animal feeds on credit. But some areas lack these institutional organisations, either because they have never been created or because they collapsed due to poor management and financial problems. Availability of reliable marketing channels is thus expected to foster the adoption of the dairy cattle technology.

Three main routes towards dairying have been identified, namely upgrading the existing local animals, getting the dairy animals at no cash cost or purchasing them. The first route enables a farmer to dramatically reduce the lumpiness of the entry cost, as the costs of raising the heifer are spread out over several years.. The drawback of this route is the significant risk of losing the animal during that period. Obtaining the animals at no cash cost is the second route toward dairying, either as a gift from parents or groups (e.g. church groups) or through projects. This entry into dairying may not be completely free (because the family/group may expect something in exchange or the project requires some conditions to be met), but the cost is difficult to assess and can be considered as negligible (as compared with the market value of the animal). Finally, the third route toward dairying is the purchase of dairy animals. The cost of a dairy cow is high compared, for example, to the monthly wage (a dairy cow costs on average 14 times the monthly wage of a rural male labourer), and farmers have to find different ways to meet the cost: savings from crop activities (either food crop sales, especially maize and potatoes or cash crop sales, coffee, tea, pyrethrum and horticulture), savings from off-farm activities or a combination of the two. The farmers who established immediately after Independence in the White Highlands benefited from Settlement Schemes whereby land and dairy animals were sold at a subsidised price: for many smallholder families in these areas, these schemes represented a real opportunity for improving their standard of living. Finally, the obvious way to finance an agricultural investment like purchasing a dairy cow is to ask for a loan. Yet, evidence from field work shows that access to credit by smallholders is limited in Kenya and may constitute an impediment to the uptake of dairy cattle technology even in the well-suited zones (in terms of agro-ecological conditions).

In this paper, we focus on the households who purchased their first dairy cow, thus excluding farmers who obtained cattle at no cash cost (because they constitute a special case that provides fewer broad insights for policy recommendations) and the farmers who progressively upgraded local animals (because this approach is practised by some farmers located in specific areas where historically, local animals are kept).

The dynamic nature of the adoption process is taken into account in two ways. First, the conditions faced by the household at the beginning of the spell are introduced through two variables, the year of the farm establishment and a dummy variable indicating if the household has benefited from the post-Independence Resettlement schemes. Secondly, an epoch dummy variable is introduced to account for the 1992 liberalisation that has modified the marketing arrangements and delivery of livestock services.

Finally, other factors identified in the literature on adoption are introduced: education and gender of the household head (female-headed households are expected to have less access to information, while education has been shown to play a positive role in the adoption of new technology). Dairying is a labour-intensive activity, so that greater household labour availability is expected to foster adoption.

3. The survey design and data collection

This study is based on a survey conducted in 1998 in eight districts located in three provinces in Kenya (Central, Eastern and Rift Valley provinces). A stratified sampling method was used to select the surveyed sublocations. A total of 1375 households were interviewed, of which 1042 have some agricultural activities. The questionnaires were completed through interviews with the household head or in his/her absence, the most senior member available or

the household member responsible for the farm. Questions referred to household characteristics and farm activities, with an emphasis on dairy production. Two main factors are suspected to both play an important role in adoption and to vary in time; owned land size and household composition. Values for these two variables were then collected at each point of time using recall questions. Key events, the years of household formation and the year of dairy cattle adoption were recorded as well.

Along with the survey data, each surveyed household was geo-referenced using a GPS unit and a detailed road network of the area was digitized using available maps from Surveys of Kenya. Road types vary widely, especially in the rural areas where many roads are only passable during the dry seasons, with the network of tarmac roads only connecting the main urban centres. In this study, three types of roads were considered, tarmac roads, other all-weather-roads and dry-weather roads. The digitised road network was supplemented with a 4-kilometer grid to fill in the areas between existing roads and allowing access to the network by farms that are not on the main road network.

Each household was then assigned to the nearest node or intersection in the network using GIS software. Distances were calculated by road types i.e. total distance was divided into three sections corresponding to the three road types. Differentiating the total distance by road type gives a more accurate measure of accessibility since travel times and costs are expected to be higher for secondary roads compared to tarmac roads. Availability of these GIS-derived distances contrasts with previous studies that were restricted in the analysis by using locational dummy variables or reported distances (thus not allowing distinction by road types).

4. A duration model specification of the adoption of dairy cattle

4.1. the credit constraint hypothesis

Access to credit for smallholders in Kenya is "inadequate" to quote government reports. In this analysis, households are classified as non-constrained (i.e. they have access to credit) if they reported to have received a loan or reported not to need credit. Those for which credit had been "too costly" are classified as non-constrained since credit supply is theoretically available to them. Constrained households are those who did not get credit for the following reasons: credit was not available or collateral was missing.

Access to credit cannot be considered exogenous in the equation of dairy adoption. In fact, we cannot postulate *a priori* that the adoption status has no influence on the access to credit. The method of instrumental variables is therefore used. Moreover, access to credit was not reported for households without cattle (the focus of the survey was on dairy producers) and there were some missing values for dairy farmers. It was thus necessary to get estimated values (1) for dairy producers in order to control for the endogeneity and (2) for non-dairy producers because values were missing. Because each household may decide to establish a farm and adopt the dairy cattle technology simultaneously, determinants of access to credit are assessed at the year of establishment. Household characteristics that are expected to influence access to credit are the head' characteristics (female-headed households are expected to be more constrained, contrary to older and more educated heads). Another household characteristic that is expected to be relevant to credit access is ethnic group membership: a dummy variable is thus introduced for households from the same tribe as the ruling party. Because the ruling party changed in 1978, households are classified as 1 if they established their farm during the period when their ethnic group was leading the country. Finally, since collateral is required to obtain a loan (either from the cooperative or directly from the state-owned institution, the Agricultural Finance Corporation(AFC)), land size is expected to play an important role. In case of rationing, credit will be first allocated to the "richer" households, i.e. whose with large land sizes. The variable introduced indicates whether household's land size is higher than the average land size in the corresponding agro-ecological zone.

For loans availability, two variables were identified. Since most of the state-provided loans are channelled to farmers through cooperatives, availability of a dairy cooperative in the neighbourhood is expected to improve access to credit. The second variable is a time-variant dummy indicating loan availability because amounts of loans offered by AFC fell dramatically since the middle of the 1980s.

A weighted logistic regression is run controlling for the sampling design (stratification and clustering) on the available data (675 dairy farmers). The results are shown in Table 1: the variables land size and institutional development are significant and with the expected sign. The overall percentage of correctly predicted observations is 62%. Predicted probabilities of access to credit are then computed and introduced as explanatory variable in the duration model.

4.2. Duration analysis

A large number of adoption studies concentrate on the cross-sectional analysis of the determinants of adoption at the farm level. The dynamics of the process are not taken into consideration and the adoption process is represented as a snapshot in time. The coefficients may be biased since there may be a time-dependent element in the adoption decision, for example accumulation of resources and knowledge. The duration model used introduces time-variant covariates in order to relate the decision of the household at each point of time to the relevant information.

In order to suggest a functional form that is to be used in the duration model estimation, the survival function for the adoption spell measured in human time is plotted (graph not shown). The survival function gives the probability that the period (in years) since household establishment is at least of length t and human time is calculated as the length between establishment and adoption. It can be shown that the probability of non-adoption declines over time, at a decreasing rate: after two years of farming, twenty-five percent of the households have adopted, while the median duration before adoption is 13 years. Because of the observed non-linearity in the profile of adoption, a Weibull specification is chosen to model the duration between establishment and adoption.

Table 2 presents the results of the Weibull specification, in a proportional hazard model (Kiefer, 1988). The agro-climatic conditions (annual precipitation/potential evapotranspiration ratio) have the strongest influence on the decision, reflecting higher possibilities of growing fodder as well as lower risks of animal diseases.

Controlling for the land size (a time-variant covariate), results show that the estimated probability of access to credit has a significant and positive effect on the decision to adopt dairy cattle technology. Farmers with large land size adopt faster, reflecting higher savings from crop activities as well greater potential for growing fodder. Education level plays a positive role in the adoption decision while older household heads tend to adopt less, reflecting a possible higher risk-aversion.

Time plays a key role in the adoption of dairy cattle technology: households who established later adopt more quickly, reflecting the on-going development of marketing facilities and better availability of services offered to dairy farmers. Yet, dairy adoption turns out to be more difficult after liberalisation, when difficulties in marketing increased with the collapse of some dairy cooperatives, and veterinary services were privatised in some areas. The other time-variant variable, milk price, plays a positive role in the adoption, showing farmers' responsiveness to better market conditions.

Finally, GIS-derived distances give interesting insights on the adoption process. Distance on all weather roads to urban centres delays the adoption decision. Also, the further the farm from Nairobi on dry weather only roads, the lower the speed of adoption. Distance on dry-weather roads is a good indicator of market accessibility at the farmer level, since they

connect the farms to the main road infrastructure. These results are consistent with the literature on transaction costs.

Conclusions:

Adoption of high grade cows by smallholders is a means to increase farm revenues and household well-being through milk sales and home consumption. By linking both survey and GIS-derived variables, this study shows that smallholders delay adoption because of poor credit accessibility and bad road infrastructures. Another important result is the effect of the liberalisation of the dairy industry: the speed of adoption has slowed down, suggesting that the conditions for adoption have worsened with the closing of some dairy cooperatives and privatisation of livestock services. Although the private sector was expected to progressively take over milk marketing and delivery of livestock services, the process is slow and hindered by administrative regulations. These results suggest that liberalisation policies may need to be accompanied by interim support for farm services and market mechanisms to maintain technology adoption trends.

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Tables:

Table 1: Logistic regression on access to credit: the dependent variable is 1 if the household has access to credit, 0 otherwise

Variables:	Odds Ratio
Household characteristics	
sex of the head (1 if male, 0 if female)	0.875
years of formal education of the head	1.019
age of the head at the beginning of the spell	1.011
dummy variable for member of the same tribe as the ruling party	1.235
dummy variable for large land size	1.526*
Credit availability	
extent of dairy cooperative activities in the neighbourhood	2.619***
dummy variable for loans availability by government	0.883

*** the coefficient is statistically significant at 1% level, * at 10%level.

Table 2: Maximum likelihood of dairy cattle adoption, Weibull hazard function

Variables	Hazard Ratio
Household human capital assets	
age of the household at the beginning of the spell	0.9894**
years of formal education of the household head	1.0358***
number of adults in the household	1.0166
Household physical assets	
total acreage owned	1.0147***
predicted probability for access to credit	5.4404***
Role of time in adoption	
idiosyncratic human time: year of farm establishment	1.0773***
idiosyncratic human time: dummy variable for "settlers"	1.5424
pure historical time: dummy variable for liberalisation	0.2189***
External factors	
milk price	5.8889***
distance to Nairobi on all weather roads, bound surface (km)	1.0010
distance to Nairobi on all weather roads, loose surface (km)	0.9990
distance to Nairobi on dry weather roads (km)	0.9632***
distance to two other urban centres on all weather roads (km)	0.9819***
availability of veterinary services in the neighbourhood	1.2152
annual precipitation / potential evapotranspiration ratio	82.3107***
Parameters of the Weibull hazard function: p	0.75

*** the coefficient is statistically significant at the 1% level, ** at 5%level.