Dynamic Changes in Dairy Technologies Uptake in the Kenya Highlands

Isabelle Baltenweck[1], Taskahi Yamano[2] and S. J. Staal[1]

[1] International Livestock Research Institute, P.O. Box 30709 Nairobi 00100, Kenya
[2] Foundation for Advanced Studies on International Development, 7-22-1 Roppongi, Minato-ku, Tokyo, 106-8677, Japan

Contact information: i.baltenweck@cgiar.org

Paper prepared for CSAE Conference, Oxford
February 2008

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Introduction

Understanding farmers' decision to adopt agricultural innovations in Developing Countries is a major field of research. Adoption of new techniques or technologies is seen to path the way to agricultural development and the analysis of the determinants of farmers' adoption is therefore crucial to formulate policy recommendations for poverty alleviation. However, most analyses look at the adoption decision as a "snapshot" decision using cross-sectional data and do not take into account the dynamics of technologies uptake.

Dairy farming is an important sector of the Kenyan economy, generating substantial income for the smallholders that produce more than half of the total milk production in Kenya (Omore *et al.* 1999). Dairy is a major enterprise for between 600,000 to 800,000 smallholder households keeping on average 2 cows on 2 hectares of land. Moreover, an estimated 365,000 waged jobs are created at the farm level (12% of the national agricultural workforce), in addition to family labour. Besides milk production for own consumption and sale, dairy provides manure and is a source of wealth and asset storage. The benefits of dairying do not however stop at the farm-gate: there are substantial employment opportunities in milk marketing and services related to dairy production (provision of feeds, veterinary, breeding and extension services). For example, almost 30,000 more jobs are generated by the marketing and processing of milk, mainly in the small scale informal sector.

The dairy sector is rapidly evolving with new players like private processors entering the market. The liberalization of the dairy industry in the early 1990s opened a new era for the dairy sector. With the progressive withdrawal of government livestock services and the end of the monopoly on the urban milk sales held by a state-managed company KCC (Kenya Cooperative Creameries), the private sector is expected to fill the gap and to provide efficient services to the Kenyan smallholders. Uncertainty remains however as to whether the private sector is willing and able to provide these services, both on the production side (veterinary, breeding and extension services) and on the marketing side. This is especially the case in areas where dairying is less market- oriented.

The purpose of this paper is to investigate the dynamics in dairy production in the period following the liberalization using panel data (cross sectional data over time) on 874 agricultural households in the Kenya Highlands. The objective is to identify opportunities for dairy growth and constraints to its development since dairy has been identified as a key pathway out of poverty for Kenyan households.

Adoption of agricultural technologies

The literature is rich in examples of static analyses linking a certain measure of adoption- or uptake- (e.g. farmers' decision to use an improved crop variety, or the extent of the land allocated to the new variety) to the adoption determinants. Determinants usually include farmer's characteristics, farm characteristics, external factors and in some cases farmers' perceptions of the new technology and use cross- sectional household survey data. However, it is well known that farmers may discontinue adoption and understanding the dynamics of uptake is needed to formulate relevant policy recommendations. This is particularly important in cases of change in external factors, for example sector liberalisation or major change in marketing channel as in the case of dairying in Kenya.

Few studies have used panel data, among which Besley and Case (1993 and 1994) and Foster and Rosenzweig, looking at the relationship between learning-by-doing and learning-from-others and the adoption of HYV seeds in India (Green Revolution).

Data and methods

The first round of data was collected between 1996 and 2000 in central and western Kenya, as part of an effort to characterize smallholder dairy systems by a collaborative team from the Ministry of Livestock Development & Fisheries, the Kenya Agricultural Research Institute (KARI), and the International Livestock Research Institute (ILRI). Similar sampling methods were applied in each case, and each survey used a variant of the same data collection instrument, conducted in a single interview of each household. The survey collected a wide variety of data on household resources, land use and livestock management practices, livestock inventory, recall of feed and other input use, and the use of livestock and extension services. Areas were grouped according to agro-ecological production potential and market access. A total of 3,330 randomly selected households were obtained. Each household was geo-referenced using GPS unit. It is therefore possible to link each household to geographical information systems (GIS) data layers for example; agro-climatic, road network and other infrastructure. More information is provided in the survey reports (Staal et al. 1998, Staal et al. 2001, and Waithaka et al. 2002).

The second round of data was collected in 2004 on 895 households previously surveyed. The questionnaire included most of the information collected during the first round. More information on the crop side was collected (see Yamono et al., 2005). Note that for simplification, the year "2000" is used to describe the data collected between 1996 and 2000, and the year "2004" is used to describe the data collected in 2004. The two datasets were combined to allow analysis of the change in choice of marketing outlets and technologies.

Since the household data available are available at two points in time, panel data techniques can be used to identify the factors influencing dairy technology uptake over time and over space. Various estimators (between, within and random) are available and by exploiting the time dimension and controlling for unobserved household heterogeneity, the results would be more efficient than previous analyses on cross sectional data. However, the analyses conducted in this paper use limited dependent variables and panel data techniques on such variables differ from the linear regression techniques. In fact, there is no fixed effects estimator for probit since heterogeneity cannot be extracted from the likelihood. A random effect estimator exists for probit using a specific estimation technique (Gauss-Hermite quadrature) but the applicability of this numeric method needs to be checked and is more applicable to small panel data, which is not the case here. On the other hand, a fixed effects estimator exists for logit model since it is possible to remove the heterogeneity by taking deviations from the means but when using logit fixed effects model, only individuals experiencing a change can be taken into account.

The method retained is therefore to analyse how systems have changed and identify the factors driving these changes. To do so, the dependent variable represents the change in farmers' uptake of a particular technology (e.g. less intensified system, no change, more intensified system). Two types of explanatory variables are included: variables evaluated at the first point of time (2000) and at the second point of time (2004) for variables for which values at the two points of time are available. GIS-derived variables are only available for 2000. When no major change for a particular variable was recorded within household, only the 2000 value was included so as to avoid introducing multicollinearity.

Each year t, the household is assumed to maximize total household income which is equal to the sum of the profits derived from the farm activities (crops and dairy activities) and the value of the family labor. The choice variables at year t are the surface devoted to each crop activity and to the livestock activity (including area under planted fodder F_t), labor for each activity, purchased inputs (including quantity of concentrates to be fed to cattle C_t, and the number of grade cattle (G_t). A farmer decides to adopt one of the three technologies under study (planted fodder, feeding concentrates and keeping grade cattle) at time t if the optimal level of technology is positive, i.e. F_t* >0, C_t* >0 and G_t* >0. At each point in time, the decision to adopt the specific technology can then be written as:

(1) $Y_{i,t} = 1$ if $Z_{i,t} * > 0 \Rightarrow X_{i,t}.\ \beta + \varepsilon_{i,t} > 0$ farmer i decides to adopt

(2) $Y_{i,t} = 1$ if $Z_{i,t} * < 0 \Rightarrow X_{i,t}.\ \beta + \varepsilon_{i,t} < 0$ farmer i decides not to adopt

with $Z=F$, C or G

where $X_{i,t.}$ is a vector of explanatory variables, β a vector of coefficients to be estimated and $\varepsilon_{i,t}$ is an independently and identically distributed farm specific ex ante shocks. Following Feder, Just and Zilberman (1985), the vector of explanatory variables includes farm and farmer's characteristics as well as external factors. Literature and fieldwork experience dictate the choice of the explanatory variables to be included in the analysis.

Among the explanatory variables is a measure of the availability of formal milk marketing outlets (dairy cooperatives and private processors). Formal milk marketing outlets offer usually more reliable outlets than alternatives ones (individual customers and small-scale traders) and some provide services like feeds and breeding services on credit. On the other hand, the price offered by the formal outlets is generally lower. Given the increasing market liberalisation currently experienced in Kenya, we test the hypothesis that low availability of formal outlets has a negative effect on dairy intensification.

Change in dairy technology uptake

Intensification in dairy farming is a multi dimensional process. The overall objective is to increase farm productivity (either through increase in milk production per cow or per unit of land, or both). To intensify, farmers therefore invest in high-producing animals (grade cattle), i.e. cattle whose genetic potential allows higher milk production than local breed cattle. Another way to increase cow productivity is to improve feeding, in particular through feeding of fodder (like Napier grass in the study area) and concentrates (like dairy meal or agro-industrial by-products). Three indicators of technology uptake are therefore analyzed, namely whether the farmer keeps grade cattle, whether concentrates are fed and whether planted fodder are fed to cattle. Grade cattle are defined as cattle with at least 50% of exotic dairy genes. Note that in the "2000 data", cattle genotype is defined as local, cross bred or high grade cattle but in the "2004 data", cattle are identified as either local or improved. To be able to compare the datasets, the two last genotypes of the "2000 data" are lumped together to be comparable to the "improved" category of the "2004 data".

Table 1 shows the dynamics in the uptake of the three technologies under consideration, as the number (and percentage) of farmers having adopted the specific technology in either the 2 periods or only one period. For example, approximately 33% of the households do not keep grade cattle in any of the two years while 45% keep them in the two periods. Thirteen percent keep grade cattle only in 2004, meaning that they are "new adopters" while 9% keep grade cattle only in 2000: these households are "dis-adopters". We assume that there has been no other change between the two dates of the survey.

A multinomial logit is estimated with the dependent variable taking values of 1 for farmers who do not keep improved cattle in any of the two years, 2 for those who keep improved cattle only keep in 2004, 3 for those who keep them only in 2000 and 4 for those who keep them in the two periods. The comparison group is the group of farmers who keep improved cattle both in 2000 and 2004. A similar analysis is run for the two other indicators of dairy intensification. Results are presented in Table 2. Goodness of fit indicators are not straight forward for a multinomial logit; predicted probabilities were computed for the four possible outcomes and the maximum predicted probability was assumed to be the predicted outcome. The comparison of the observed and the predicted outcomes shows that the various models predict correctly between 56% and 61% of the observations.

For each indicator, there are three sets of results: the first column of results gives the marginal effect of a one-unit change in the explanatory variables on the probability of being a non-adopter, compared to the probability of being an adopter in both years (which we call a "continuous adopter"). The second set of results show the marginal effect of being a "new adopter" (an adopter only in the 2004 dataset), compared to a "continuous adopter" while the third set of results show the marginal effect of being a "dis-adopter" (an adopter only in the 2000 dataset), compared to a "continuous adopter". Maybe because the dis-adopters represent a small proportion of the farmers, some of the results for this category of farmers are more difficult to interpret and should be interpreted with caution.

In terms of survey derived variables, the education level of the household head has a significant effect on the decision to keep grade cattle and concentrate feeding. In fact, more educated households are more likely to be continuous adopters of grade cattle concentrate feeding technologies, results that confirm the positive relationship between education and uptake of dairy farming found in cross-sectional analyses. A somehow unexpected result is that more educated farmers are more likely to discontinue concentrate feeding (compared to those feeding them in both years). The second variable that gives interesting results is the number of adults in the household: the result showing that farmers with more adult members in 2004 have a higher probability of starting dairy (new adopters of grade cattle) and starting concentrate feeding is consistent with the observations that dairy is a labour-intensive activity. Also, households with more adult members are more likely to be continuous adopter of concentrate feeding technology and less likely to stop it. Other variables capturing household composition are the ratio of female adults and the dependency ratio. Farmers with more dependents have higher likelihood of starting dairy (grade cattle technology), which may reflect households' willingness to secure more milk and income through intensive farming given higher family needs. On the other hand, households with higher dependency ratio are more likely to dis-adopt fodder planting and not to grow fodder in any of the two periods. Finally and as expected, older households are less likely to be new adopters and more likely to dis-adopt grade cattle technology, while female-headed households are less likely to stop dairy farming.

The land size results show that compared to those who keep grade cattle in both surveys, farmers with no grade cattle in any of the two rounds and new adopters have less land, suggesting that large land size is needed for continuous uptake but farmers with small land size are however able to start keeping grade cattle. For the concentrate feeding regression, results are difficult to interpret: although larger land size in the first period is positively associated with continuous adoption, the land size in the second period has the opposite effect, maybe due to the fact that additional land is used to grow fodder at the expense of using concentrates. On the other hand, more land in the first period is associated with increased likelihood of discontinuing concentrate feeding but the opposite holds for land size in the second period. Farmers who start growing fodder are those with less land, suggesting that under decreasing land availability, farmers find it appropriate to intensify dairy production by allocating some land to a dairy specialised crop.

Now turning to the GIS-derived variables, the indicator of climatic conditions (PPE) has a significant effect on each technology decision. Farmers in good climatic areas have a higher probability to be continuous adopters of grade cattle, concentrate feeding and fodder technologies. The effect of human population density is significant in the fodder regression whereby farmers in high density areas are more likely to be continuous adopters, a result consistent with Boserup's hypothesis. On the other hand and unexpectedly, new adopters of fodder technology are less likely to be in high population densities areas, and those dis-adopting grade cattle technology are in highly populated areas.

The market access variables show interesting results: good market access (low distance to urban centres and travel time to Nairobi) increase the likelihood of being a continuous adopter of grade cattle technology while new adoptions are more likely in good market access areas. On the other hand, dis-adoption seems to occur in these same areas. Short travel time to the capital city Nairobi also increases farmers' likelihood to be continuous adopters of concentrates feeding and fodder growing. Access to urban centres is also a significant factor in the other two regressions: increased distance (low market access) is positively correlated with the probability of not growing fodder and feeding concentrates in any of the 2 periods. For concentrate feeding, the other results for the distance to urban centres variable are however unexpected.

Finally, farmers in areas with high availability of formal milk marketing outlets (as captured by the proportion of farmers selling to those outlets) are more likely to be continuous adopters of grade cattle and concentrate feeding technologies. This result does not contradict the hypothesis tested that high availability of formal milk marketing outlets has a positive effect on dairy intensification. On the other hand, in these areas, farmers are also less likely to start growing fodder (new adopter) and more likely to dis-adopt this technology, a result that contradicts the above-mentioned hypothesis.

Conclusions

A number of analyses have previously been conducted on uptake of agricultural innovations in Developing countries and uptake of dairy technologies in particular but most analyses use cross- sectional data and therefore analyzing a dynamic process in a static way. In this paper, we used panel data collected on 874 farmers over 2 periods of time to analyze the dynamics of uptake of dairy technologies. Different indicators of dairy technologies were used and the results confirm the results of cross sectional analyses like the effect of education and also shed more light on the effect of land holdings. Previous analyses had shown that the effect is relatively limited and this analysis suggests that large land holdings may be needed for continuous uptake, while smaller farms are able to keep improved cattle, but may not always be able to maintain the animals due to land and/or cash constraints.

The situation of the milk market is evolving rapidly, with important changes in the type of marketing outlets available to smallholders. Although results show that availability of formal milk marketing outlets has a positive effect on farmers' decision to continuously keep improved cattle and feed concentrates, it can also be seen that farmers in these areas are less likely to start growing fodder and more likely to dis-adopt this technology.. Farmers therefore seem to adjust rapidly to the changes in the marketing options and additional analysis is needed to better comprehend the relationship between market liberalization and dairy intensification.

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Table 1: Change in uptake of dairy technologies over time (number and percentages of farmers)

	grade cattle	feeding concentrate	planted fodder
Never adopter	282 (33%)	437 (55%)	276 (32%)
New adopter (adopter only in 2004)	117 (13%)	118 (15%)	207 (24%)
Dis-adopter (adopter only in 2000)	78 (9%)	122 (16%)	64 (8%)
Continuous adopter (adopter in both years)	394 (45%)	111 (14%)	312 (36%)

Table 2: Marginal effects of multinomial logit for three indicators of dairy intensification (marginal effects)

variable	base change	decision to keep improved cattle			decision to feed concentrates			decision to grow planted fodder		
		Never adopter	New adopter	Dis-adopter	Never adopter	New adopter	Dis-adopter	Never adopter	New adopter	Dis-adopter
1 if female headed household (2000)	1	1.391	6.446	-4.816**	1.642	-2.480	-3.458	0.303	-0.719	0.883
age of the household head (2000)	1	0.208	-0.321**	0.166*	0.297	-0.137	-0.018	0.044	0.082	0.101
years of education of the hh head (2000)	1	-1.209**	-0.181	0.236	-1.498***	-0.304	0.881**	-0.755	0.229	0.234
number of adults in the household (2000)	1	0.206	-0.729	-0.068	0.925	-0.763	1.392	-1.555	0.104	0.349
number of adults in the household (2004)	1	-0.110	1.566**	-0.978	-1.961*	1.594**	-1.956**	0.816	0.325	-0.640
ratio of female adults over total adults (2000)	0.1	0.619	-0.671	-0.395	1.704	-0.563	-0.236	-0.014	0.673	-0.256
ratio of female adults over total adults (2004)	0.1	-0.654	-0.238	1.505***	0.820	1.033	0.158	0.243	1.111	0.171
dependency ratio (2000)	0.1	1.119	-0.750	0.434	1.005	0.174	0.262	-0.187	0.383	0.983*
dependency ratio (2004)	0.1	1.006	2.115**	-0.933	-0.118	-0.337	-0.067	2.418**	-0.637	-0.651
land size (2000)	1	-2.513***	-1.380**	-0.048	-1.946***	0.090	1.055**	-0.846	-1.014*	0.880***
land size (2004)	1	0.446	0.278	-0.500	0.963**	0.060	-0.999**	0.362	-0.159	-0.232
population density	100	-1.267	-0.819	1.017*	0.530	0.629	-0.504	-5.044***	-1.784*	0.940
PPE	0.1	-10.180***	0.551	-0.213	-7.546***	3.586***	2.193**	-8.492***	-0.351	0.189

variable	base change	decision to keep improved cattle: Never adopter	New adopter	Dis-adopter	decision to feed concentrates: Never adopter	New adopter	Dis-adopter	decision to grow planted fodder: Never adopter	New adopter	Dis-adopter
distance to the 2 nearest large urban centres, tarmac roads	1	-0.215	-0.142	0.050	-0.025	0.052	-0.029	0.144	-0.186	0.010
distance to the 2 nearest large urban centres, other all weather roads	1	1.007***	0.120	-0.302*	0.822***	0.314*	-0.502**	0.903***	-0.254	-0.061
distance to the 2 nearest large urban centres, dry-weather roads	1	-0.075	-0.866*	-0.313	0.279	-0.691	0.190	-0.035	-0.326	0.088
travel time to Nairobi	1	14.735***	0.386	0.499	16.170***	-7.176***	-4.563***	12.735***	-2.692	1.279
Proportion of farmers selling to formal outlets (2000)	0.1	-4.918***	-1.420	0.517	-3.864***	0.085	1.653**	-1.402	-2.681**	0.892*
Number of obs			798			720			788	
Log likelihood			-793.26			-707.53			-843.80	
Pseudo R2			0.1804			0.1596			0.1495	
% correctly predicted			61.40%			60.69%			55.58%	

*** indicates that the coefficient is statistically significant at 1%, ** at 5% and * at 10%.