Dynamic Changes in Dairy Technologies Uptake in the Kenya Highlands

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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 milk 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. This was important because it was then possible to link each household to the geographical information systems (GIS) data 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 the first difference between 2000 and 2004 for the variables for which values at the two points of time are available.

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 (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, a relevant question is

how do farmers adjust their dairy activities? The hypothesis tested is whether the decreased availability of formal outlets has a negative effect on dairy intensification.

Change in dairy technology uptake

Three indicators of technology uptake are analyzed, namely whether the farmer keeps improved (or grade) cattle, whether concentrates are fed and whether planted fodder (like Napier grass) are fed to cattle. Improved 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 improved cattle in any of the two years while 45% keep them in the two periods. Thirteen percent keep improved cattle only in 2004 while 9% keep improved cattle only in 2000.

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 4 possible outcome and the maximum predicted probability was assumed to be the predicted outcome. The comparison of the observed and the predicted outcomes shows that the model predicts correctly between 53% and 59% of the observations

A number of variables are significant across the different outcomes and for the different indicators. It is interesting to note that younger households are those who started keeping improved cattle while aging has a negative effect on discontinuing grade cattle keeping (compared to the farmers who keep improved cattle in the 2 rounds). Also, more educated households are less likely not to keep cattle and not to feed concentrate in any of the 2 years while being more educated over time has a negative effect on stopping dairy farming, results that confirm the positive relationship between education and uptake of dairy farming. A somehow unexpected result is that more educated farmers are more likely to discontinue concentrate feeding (compared to those feeding them in both years). On the other hand, households with increase years of education over time have a higher likelihood of starting feeding concentrates.

Getting more adult members over time has a positive effect on starting dairy farming, illustrating the labour intensity of the activity. In fact, grade cattle are usually kept in stalls where they are fed with fodder unlike local cattle that graze pasture and therefore require less labour. Also, households with more adult members are more likely to start feeding concentrates and less likely to stop it, illustrating the fact that feeding concentrates is labour intensive.

A surprising result is the one relative to the ratio of female adults in the households: higher and increasing ratios have a negative effect on the decision to keep grade cattle, a result that is unexpected given the role that women play in caring for the cattle on most farms.

The land size results show that compared to those who keep improved cattle in both rounds, farmers with no improved cattle in any of the two rounds and those with improved cattle only in the second round have less land, suggesting that large land size is needed for continuous uptake; in other words, although smaller farms are able to keep improved cattle, they may not always be able to maintain the animals. For the concentrate feeding regression, increased land size over time increases the likelihood of not feeding concentrates in any of the two periods, suggesting that the additional land is used for planted fodder at the expense of using concentrates. On the other hand, more land tends to be associated with decreased likelihood of discontinuing concentrate feeding (compared to farmers feeding concentrates in the two periods). 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. The effect of human population density is significant in the fodder regression whereby farmers in low density areas do not intensify dairy production, a result that does not contradict with Boserup's hypothesis.

The market access variables show interesting results: farmers who don't keep improved cattle and do not grow planted fodder in any of the two periods have significantly lower market access (distance on other all-weather roads and travel time to Nairobi). On the other hand, farmers with long distances on dry-weather roads are less likely to start dairy farming cattle. This therefore confirms previous results that for "permanent" dairy adoption, market access is important. Some of the results for the concentrate feeding regression are counter-intuitive although the observation that farmers far from Nairobi are more likely not to intensify dairy production still holds.

Farmers with less favourable climatic characteristics are more likely not to keep improved cattle in any of the two periods; on the other hand, the climatic characteristics do not

have a significant effect on whether the farmer keeps improved cattle in one round (compared to the farmers who keep improved cattle in both rounds).

Farmers with low availability of formal milk marketing outlets in their neighbourhood (as captured by the proportion of farmers selling to those outlets) are more likely not to keep grade cattle and to feed concentrates in any of the two periods. This result does not contradict the hypothesis tested that low availability of formal milk marketing outlets has a negative effect on dairy intensification. Moreover in areas experiencing increased sale to formal outlets, farmers are more likely to feed concentrates in both period, compared to those not feeding in any of the two periods. On the other hand, increased availability of formal milk outlets has a positive effect on discontinuing concentrates feeding and growing planted fodder, 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. This is important policy implications in light of the recent land policy reforms suggested in Kenya.

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 keep improved cattle, it can also be seen that farmers in areas with fewer formal marketing outlets are induced to increase their level of inputs like concentrates feeding- suggesting that the alternative channels offer more profitable returns. 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)

	improved cattle	feeding concentrate	planted fodder
no in 2000 and no in 2004	282 (33%)	437 (55%)	276 (32%)
no in 2000 and yes in 2004	117 (13%)	118 (15%)	207 (24%)
yes in 2000 and no in 2004	78 (9%)	122 (16%)	64 (8%)
yes in 2000 and yes in 2004	394 (45)	111 (14%)	312 (36%)

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

		decision to keep improved cattle			decision to feed concentrates			decision to grow planted fodder		
	base change	no in '00, no in '04	no in '00, yes in '04	yes in '00, no in '04	no in '00, no in '04	no in '00, yes in '04	yes in '00, no in '04	no in '00, no in '04	no in '00, yes in '04	yes in '00, no in '04
1 if female headed household	1	4.83	4.02	-7.07***	5.42	-0.63	-7.55**	1.85	3.11	-0.53
Change in (female headed household)	1	6.84	-3.88	-5.90*	5.67	3.19	-6.86	3.33	7.03	-2.52
age of the household head	1	0.14	-0.30**	0.08	0.15	-0.07	0.08	-0.16	0.22	0.12
Change in age of household head	1	-0.03	-0.05	-0.20*	-0.19	0.00	0.22	-0.43**	0.44**	0.04
years of education of the hh head	1	-1.77***	-0.02	-0.08	-2.05***	0.21	0.86*	-1.00	0.40	0.19
Change in years of education	1	-0.82	0.36	-0.71**	-0.96	0.98**	0.03	-0.53	0.22	-0.08
number of adults in the household	1	0.15	0.81	-0.92	-0.57	0.84	-1.08	-0.36	0.18	-0.40
Change in number of adults	1	0.18	1.48*	-0.87	-1.59	1.43*	-2.13**	1.08	0.22	-0.66
ratio of female adults over total adults	0.1	-0.83	-0.73	1.11*	2.07	0.49	0.31	-0.01	1.73	-0.03
Change in ratio of female adults	0.1	-0.82	-0.21	1.50***	0.43	1.00	0.52	-0.01	1.08	0.24
dependency ratio	0.1	2.15*	1.30	-0.47	1.10	-0.11	0.01	2.42**	-0.34	0.24
Change in dependency ratio	0.1	1.06	2.07**	-0.85	0.20	-0.55	-0.14	2.56**	-0.66	-0.68
land size	1	-1.65**	-1.33**	-0.54	-0.77	0.03	-0.06	-0.56	-1.08*	0.65**

Change in land size	1	0.55*	0.27	-0.42	1.12**	0.02	-1.14**	0.36	-0.18	-0.24
population density	100	-1.23	-0.91	0.98*	0.58	0.56	-0.46	-5.00***	-1.91*	0.96
PPE	0.1	-10.09***	0.37	-0.38	-7.06***	3.36***	1.87*	-8.77***	-0.05	0.12
distance to the 2 nearest large urban centres, tarmac roads	1	-0.25*	-0.15	0.03	-0.06	0.07	-0.01	0.15	-0.18	0.01
distance to the 2 nearest large urban centres, other all weather roads	1	1.01***	0.13	-0.28	0.86**	0.32*	-0.51**	0.93***	-0.24	-0.09
distance to the 2 nearest large urban centres, dry-weather roads	1	-0.25	-0.89*	-0.38	0.15	-0.62	0.29	-0.11	-0.28	0.10
travel time to Nairobi	1	14.48***	0.73	0.71	15.04***	-6.68	-3.62	12.51***	-2.71	1.54
Proportion of farmers selling to formal outlets	0.1	-5.37***	-1.27	0.52	-5.61***	0.60	2.94	-1.64	-2.95**	1.23*
Change in proportion farmers selling to formal outlets	0.1	-1.01	0.31	-0.01	-3.57*	1.18	2.84	-0.82	-0.19	0.77
Number of observations			784			710			784	
Pseudo R2			0.19			0.17			0.15	
% correctly predicted			59%			55%			53%	

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