

The labour market is thus characterised by the following inequality: $w^w < w^m < w^{hired}$. Because of the difference between the women and the men wage rates on the one hand, and family and hired wage rate on the other hand, the labour market is characterised by regimes created by the price bands across the categories of workers (Sadoulet *et al.* 1998; Sadoulet and de Janvry 1995). According to this literature, membership to a specific labour regime depends on the farmer's endowment in family labour: a farmer uses family women labour first, then family men and, if still needed, hires external workers. It is further assumed that only men are hired for dairy activities in order for the labour regimes to predict that family labour is used first (women and men) before hiring external workers.

3.3. The model

Each year t , the household is assumed to maximise 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 labour. The choice variables at year t are the surface devoted to each crop activity ($H_{j,t}$) and to the livestock activity ($H_{c,t}$), labour for each activity ($L_{j,t}$ for crops and $L_{c,t}$ for livestock), purchased inputs ($V_{j,t}$ for crops and $V_{c,t}$ for livestock) and the number of grade cattle (C_t). $M_{j,t}$ is the quantity of manure obtained from cattle that is used in the different crop activities.

The entry cost into dairying is modelled as the factor $p_{c,t} \cdot i_t \cdot C_t$ where $p_{c,t}$ is the cost of a grade cow and i_t the interest rate charged on the loan at year t . If the farmer had no access to credit, i_t is equal to 1, meaning that the farmer bears the full cost of the purchase in one year. It is hypothesised that access to credit is a function of farmers' characteristics (especially land ownership) and availability of credit supply.

Crop production functions are defined by $f_j(\bullet)$ and the milk production function by $g(\bullet)$. The quantity of fodder fed to the animals is supposed to be taken into account by both the land allocated to dairying (fodder grown on farm) and the purchased inputs (purchased feeding). j are the different crops and p_j are prices. Because milk is a bulky and highly perishable product that needs to be sold daily, the milk market is characterised by high transaction costs TC_m .

Total household income⁴, u_t , is equal to the sum of the farm profits Π_t^{farm} and the total value of family labour. The household income u_t is written as:

$$(1) u_t = \Pi^{farm} + w^m \cdot \bar{L}^m + w^w \cdot \bar{L}^w = \sum_j \Pi^{crops} + \Pi^{cattle} + w^m \cdot \bar{L}^m + w^w \cdot \bar{L}^w$$

$$= \sum_j p_j \cdot f_j(H_j, L_j, V_j, M_j; Z^h, Z_f^r) + (p_m - TC_m) \cdot g(C, H_c, L_c, V_c; Z^h, Z_c^r) - p_c \cdot i \cdot C$$

$$- p_v \cdot (\sum_j V_j + V_c) - w^m \cdot (\sum_j L_j^m + L_c^m) - w^w \cdot (\sum_j L_j^w + L_c^w) - s \cdot (L_c^h) + w^m \cdot \bar{L}^m + w^w \cdot \bar{L}^w$$

with $L_j = L_j^m + L_j^w$

$$L_c = L_c^m + L_c^w + L_c^b$$

and where $M_j = \alpha_j \cdot C$ (with $\alpha_j > 0$), L_j^m is the men labour for crop activity j , L_j^w is the women labour for crop activity j , L_c^m is the men labour for dairy activities, L_c^w is the women labour for dairy activities and L_c^b represent hired labour for dairy activities. Labour costs for dairying are augmented by the supervision costs s . Total men family labour is \bar{L}^m and women family labour is \bar{L}^w .

Z^h represent the household characteristics that influence the farm productivity, such as the age, sex and education level of the household head, Z_f^r are the regional characteristics affecting the crop activities (land quality and agro-climatic conditions) and Z_c^r are characteristics specific to the dairy enterprise and include the incidence of animal diseases.

The production functions f_j and g are supposed to be increasing, strictly quasi concave and differentiable continuously. Because of the risk of animal diseases, the household's preferences are based on the expected household income $E(u)$ and the variance of the income $V(u)$. The household maximises: $E(u) - \phi \cdot V(u)$, where ϕ is the coefficient of absolute risk aversion. It is further hypothesised that crop activities and the value of family labour are not risky. By consequence the variance of the profits are equal to the variance of the cattle revenues. More formally:

$$(2) Var(\pi^{farm}) = Var(\pi^{cattle}) = Var((p_m - TC_m) \cdot g(\bullet)) = (p_m - TC_m)^2 \cdot Var(g(\bullet))$$

$$= (p_m - TC_m)^2 \cdot C^2 \cdot \sigma^2$$

where $\sigma^2 = Var(g(\bullet) / C) = \text{constant}$

The last expression implies that the risk of the dairy activities increases with the number of animals: the higher the number of animals, the higher the risk of loosing them. It should be noted

⁴ To save on writing, the index t is no more indicated in the following equations.

that the inputs (e.g. veterinary services) have no effect on the risk of the dairy activity in this formulation.

A liquidity constraint is introduced: the household has frequent cash needs (inputs for crop activities, feed and veterinary services for the dairy activity) while farm incomes are generally seasonal, except the milk sales as noted before.

Finally, land is considered to be a quasi-fixed factor of production and the land constraint is supposed to be always binding, so that:

$$(3) \sum_j H_j = \bar{H} - H_c$$

where \bar{H} is the quantity of land owned by the household. In equation (4), the Lagrangian is maximised with respect to all the H except one in order to respect equation (3). To simplify the writing, the surface allocated to dairying H_c is omitted.

The farmer's problem is solved with a Lagrangian:

$$(4) \max_{\substack{H_j, L_j^k, L_c^k, \\ L_c^h, V_j, V_c, C}} \left\{ \begin{array}{l} \sum_j p_j \cdot f_j(\bullet) + (p_m - TC_m) \cdot g(\bullet) - p_c \cdot i \cdot C - p_v \cdot (\sum_j V_j + V_c) \\ - \sum_{k=m,w} w^k \cdot (\sum_j L_j^k + L_c^k) - s \cdot (L_c^h) + \sum_{k=m,w} w^k \cdot \bar{L}^k - \phi \cdot (p_m - TC_m)^2 \cdot C^2 \cdot \sigma^2 \\ + \lambda \cdot \left[(p_m - TC_m) \cdot (g(\bullet) - \bar{C}_m) - p_v \cdot (\sum_j V_j + V_c) - \sum_{k=m,w} w^k \cdot (\sum_j L_j^k + L_c^k) - s \cdot (L_c^h) + \sum_{k=m,w} w^k \cdot \bar{L}^k \right] \end{array} \right\}$$

and $i = i(\bar{H}; Z^i)$ where Z^i represents the characteristics influencing the farmer's access to credit status. \bar{C}_m is milk home consumption and λ is the Lagrangian multiplier associated with the liquidity constraint.

The first order conditions are obtained by deriving the above expression with respect to the choice variables. The assumptions on $f(\bullet)$ and $g(\bullet)$ ensure that the problem admits only one solution given by the Kuhn-Tucker relations:

$$(5.a) -p_j \cdot \frac{\partial f}{\partial H_j} + (p_m - TC_m) \cdot \frac{\partial g}{\partial H_c} (1+\lambda) = 0, \quad \forall j$$

$$(5.b) p_j \cdot \frac{\partial f}{\partial L^k_j} - w^k (1+\lambda) = 0, \quad \forall j \text{ for } k = m, w$$

$$(5.c) [(p_m - TC_m) \cdot \frac{\partial g}{\partial L^k_c} - w^k] (1+\lambda) = 0, \quad \text{for } k = m, w$$

$$(5.d) [(p_m - TC_m) \cdot \frac{\partial g}{\partial L^h_c} - w^k - s] (1+\lambda) = 0, \quad \text{for } k = m, w$$

$$(5.e) p_j \cdot \frac{\partial f}{\partial V_j} - p_v (1+\lambda) = 0, \quad \forall j$$

$$(5.f) [(p_m - TC_m) \cdot \frac{\partial g}{\partial V_c} - p_v] (1+\lambda) = 0$$

$$(5.g) \sum p_j \cdot \frac{\alpha_j \partial f}{\partial M_j} + (p_m - TC_m) \cdot \frac{\partial g}{\partial C} \cdot (1+\lambda) - 2\phi \cdot (p_m - TC_m)^2 \cdot C \cdot \sigma^2 - p_c \cdot i = 0, \quad \forall j$$

$$(5.h) \lambda \cdot XX = 0, \lambda \geq 0, XX \geq 0, \lambda = 0 \Leftrightarrow XX > 0$$

$$\text{and } XX = (p_m - TC_m) \cdot (g(\bullet) - \bar{C}_m) - p_v \cdot (\sum_j V_j + V_c) - \sum_{k=m,w} w^k \cdot (\sum_j L^k_j + L^k_c) - s \cdot (L^h_c) + \sum_{k=m,w} w^k \cdot \bar{L}^k$$

The last equation (5.h) is the Kuhn-Tucker condition on liquidity constraint. If the constraint is binding ($XX=0$), the parameter λ is positive and reflects the extent of the constraint (the more the constraint is binding, the higher λ). If the constraint is not binding, the expression XX is positive, so that λ is equal to zero.

Equation (5.a) shows that land is allocated such that the value marginal productivity of land is equal between all types of activities, each crop and cattle. In equations (5.b) to (5.f), the value marginal productivity of the different inputs equals the marginal cost. The costs of the inputs for the crop activities are augmented by the factor $(1+\lambda)$, which is positive if the liquidity constraint is binding. In equation (5.g), the marginal value of the milk production is augmented by the same factor, indicating the role of milk sales to loose the liquidity constraint. In other words, if the liquidity is binding, there is a positive "mark-up" on milk sales and on the costs of the inputs: the mark-up associated with milk sales has a positive effect on the liquidity constraint, while the effect is negative for the mark-up associated with the costs of inputs (Sadoulet and de Janvry 1995). The hypothesis is that all households are liquidity constrained, so that the levels of the choice variables are function of the whole set of exogenous variables, through the multiplier λ .

Equation (5.g) is the first order condition associated with the optimum number of animals C^* . C^* verifies that the marginal revenues from dairying (including the value of manure in terms of increased yields) equal the marginal costs (including the risks).

The structural model is then solved for the reduced form that gives the endogenous variables as a function of the exogenous variables. A household adopts dairy cattle if its maximisation problem results in a positive optimal number of animals: $C_t^* > 0$. It is the reduced form that is estimated:

$$(6) C_t^* = C_t^*(i_t, p_{c,t}, \overline{H}_t, p_{m,t}, TC_m, w_t^m, w_t^w, s, L_t^m, L_t^w, p_{j,t}, p_{v,t}, Z_t^h, Z_{f,t}^r, Z_{c,t}^r, \sigma^2)$$

The exogenous variables can then be grouped into categories that are more explicit. The following table presents the link between the categories and the variables in the equation:

Table 1: Categories of variables	
Theoretical model	Variable in the equation
Access to credit	i_t
Household characteristics	
- Household head characteristics	Z_t^h
- Other household characteristics	$\overline{H}_t, L_t^m, L_t^w, Z_t^b, \sigma^2$
Prices and transaction costs	
- Milk price and transaction costs	$p_{m,t}, TC_m$
- Wage rate & supervision costs	w_t^m, w_t^w, s
- Other prices	$p_{c,t}, p_{j,t}, p_{v,t}$
Area characteristics	
- Specific to dairying	$Z_{c,t}^r$
- Both for dairying and crop activities	$Z_{c,t}^r, Z_{f,t}^r$

Equation (6) identifies the variables affecting the farmer's decision to enter into dairying. The next section aims at determining the expected effect of these variables on the decision.

3.4. Predictions of the model

3.4.1. Access to credit

The effect of access to credit on the decision is formally derived by calculating the total derivatives on equation (5.g). This is the case because the access to credit (variable i) only appears in the equation (5.g).

$$(7) \frac{dC}{di} = \frac{p_c}{\sum p_j \cdot \alpha_j^2 \frac{\partial^2 f}{\partial M^2} + (p_m - TC_m) \cdot (1 + \lambda) \cdot \frac{\partial^2 g}{\partial C^2} - 2 \cdot \phi \cdot p_m^2 \cdot \sigma_c^2}$$

This expression is unambiguously negative since the numerator is positive and the denominator is negative (if usual signs are assumed for the production functions). A higher level of i , meaning less access to credit (recalling that $i=1$ for households with no access to credit), correspond to a lower probability to adopt grade cows.

The tested hypothesis is thus whether access to credit facilitates the adoption of grade cattle technology. A similar hypothesis is tested by Dercon (1998) in the case of Tanzanian smallholders' decision to enter into cattle rearing. In this case, households keep cattle for their contribution to the land via manure and animal traction, for the offspring and livestock products. Because of incomplete credit markets, households have no choice but to accumulate savings to finance the entry cost into the activity. The estimation results of a Probit model are consistent with the hypothesis of lack of credit facilities since entry into cattle rearing is mainly explained by the households' income earning capacities (endowments in male labour and land). The test of the hypothesis of missing (or incomplete) credit markets is however indirect since no data are available on household's access to credit.

The expected effects of the other variables on adoption are predicted intuitively and are explained as follows:

3.4.2. Household characteristics

- Household head characteristics

Household head characteristics that are expected to play a role in the adoption are the gender, age and education. It is assumed that female-headed households have less access to information and formal marketing channels, two factors that are usually associated with adoption.

As for age, younger heads are usually more willing to innovate, while older heads have on average higher financial capacities to bear with the costs of the project. The effect of age is by consequence ambiguous.

Finally, education of the household head has been identified by the literature as a major determinant of adoption, since "education enhances one's ability to receive, decode and understand information" (Lin 1991). Dairying requires different skills than those used in crop activities and by consequence, farmers with a high level of education are expected to adopt more.

- Other household characteristics

The first characteristic is land size: land size is usually positively associated with adoption. It is expected that farmers with a larger land size are more induced to adopt because of the higher opportunities of growing fodder on-farm and/or having grazing pasture. Moreover land size is a proxy for wealth, which is negatively correlated with risk aversion: large land size is thus expected to foster adoption through the risk aversion channel.

The second characteristic that needs to be taken into account is the family labour availability. Because dairying is a labour-intensive activity, availability of family labour is expected to play a positive role in the adoption. Labour is needed every day, all year long for feeding and milking the animals. The description of the functioning of the labour market has shown that women labour is less costly (section 3.2.). The decision to adopt grade cattle is thus an increasing function of the availability of family female labour. The empirical analysis introduces male and female labour separately. This is consistent with the literature (Tangka *et al.* 1999) and fieldwork, which show that the daily tasks associated with dairying are mostly accomplished by the female members.

The issue of hired labour, either to perform the tasks associated with dairying or to complement family labour, is taken into account through the wage rate and is discussed in section 3.4.3.

Finally, another household characteristic is the coefficient of absolute risk aversion ϕ . This variable is not introduced explicitly in the analysis. In fact, experiments have suggested that the spreads in risk aversion among farmers in the same agronomic environment are relatively small (Binswanger and Sillers 1983). By consequence, it is unlikely that the differences in risk aversion among farmers are a "primary source of differences in *adoption among farmers in the same agronomic environment*" (p. 13). Household- level variables are introduced in order to control for the agronomic conditions; it is thus assumed that omitting the (not observed) level of risk aversion will not entail a large bias.

3.4.3. Prices and transaction costs

- Milk price and transaction costs

Milk price affects positively the profitability of the dairy enterprise: a higher milk price is expected to increase the probability of adoption. In a study of the long term relationships between environmental change, population growth, production and technological change in Machakos district (one of the area covered by the survey), Ackello- Ogotu (1991) considers that the increase in milk price is an important factor to explain the farmers' decision to start dairy farming.

However, milk marketing is characterised by high transaction costs since milk is a bulky, highly perishable product that needs to be sold daily. Moreover, road infrastructures are quite poor in some areas, making milk transport a long and expensive process. By consequence, distances of the farm to urban centres are expected to play a role in the decision to adopt grade cattle technology. In a study of the adoption of high yielding variety wheat seeds in India, Mann (1989) introduces the distance between the village and the market, but without distinguishing between the different types of roads as in the present analysis. The importance of taking into account the household's position is stressed also by Omamo (1998) in his study on farm to market transactions costs in Kenya; when transactions costs, approximated by the distance farm- market are ignored, farmers' behaviour may appear non efficient since the sale price of cash crops is over- estimated and the purchase price of food crops is under- estimated.

To mitigate the relative disadvantage of smallholders on the milk market, dairy co-operatives are in charge of organising milk collection centres, collecting the milk of scattered small producers and finally marketing the milk (Staal *et al.* 1997). It is thus postulated that availability of a reliable outlet for milk sales, like a dairy co-operative, will foster the adoption. Moreover, some co-operatives provide services (credit to buy feed and livestock services), and these are additional reasons to hypothesise that the availability of a dairy co-operative has a positive influence on the decision to keep dairy cattle. Availability of a “reliable” marketing channel is related to what can be called “network externalities” whereby farmers have an incentive to adopt if there is already a marketing network in place.

- *Wage rate*

Wage rate enters the model through the cost of hired labour. The decision to hire labour is introduced by this variable. Because a higher wage rate discourages the hiring of external labourers, a higher wage rate is expected to diminish the incentives for adoption, recalling that dairying is a labour-intensive activity.

- *Other prices*

Other prices include prices of a grade cow, of inputs and of crops. The first two prices have a negative expected effect on adoption since they increase the costs of the dairy enterprise. The effect of crop prices is undetermined since by increasing the profits from crops, it makes dairying less attractive (negative expected effect) while at the same time it increases savings, thus enabling the farmer to finance the entry cost (positive expected effect).

3.4.4. Area characteristics

- Characteristics specific to dairying

Because rearing grade cows is a very specific activity (compared to indigenous cattle and crops activities), availability of extension, veterinary and artificial insemination services are expected to foster adoption. These services increase the expected profitability of the enterprise. More particularly, extension services have been identified in the literature as a means to complement formal education. It is thus expected that the availability of these services increase adoption.

- Characteristics both for dairying and crop activities

Climatic variables are introduced in order to control for the suitability of the area for crops and fodder cultivation.

4. Access to credit: definition, estimation issue and econometric estimation

Access to credit is expected to play a key role in the decision to keep grade cows. In this section, access to credit is defined both theoretically and empirically. The issue of endogeneity of the variable in the equation of adoption is then raised and the method to deal with it is explained and justified. Finally the econometric estimation of the farmer' status of access to credit is presented.

4.1. Definition of access to credit

Binswanger and Sillers (1983) identify two main reasons that can explain why farmers face differential conditions on the credit market. The first reason deals with the issue of fixed transaction costs on the credit market; the fact that banks ask for a collateral constitutes the second reason.

Fixed transaction costs arise on the credit markets because of the need for the lender to acquire some information about the potential borrower (c.f. AFC rules section 2.1.) and the nature of the project. A lender will then accept to lend to a small farmer only if it can charge "the proportionally larger transaction costs of small loans to the small borrower as either a fixed fee or an increased interest rate" (Binswanger and Sillers 1983, p. 14). If this is not possible, the transaction will not take place and the small farmer will be credit constrained. In the case of adoption of grade cattle technology, loan sizes are expected to be equal between farmers: fixed transaction costs are thus charged on loans of the same size and credit constraints in this case do not to arise through this channel. On the other hand, "rich" farmers may ask for higher loans to

purchase a more expensive animal, compared to the case of a "poor" farmer who may choose to purchase a smaller cow, less expensive. The transaction costs argument thus may arise through this channel.

The other main source of credit constraint for small farmers is the lack of collateral as pointed out by Eswaran and Kotwal (1986). Farmers with small land size are denied credit because they are unable to offer to the lender the needed security. More specifically, imposing a collateral generates three changes: (1) the lender's expected return is increased and the borrower's expected return is lower; (2) the risk of losing the principal is shifted (partly or fully) from the lender to the borrower; (3) the borrowers are more induced to repay the loan since the utility cost of default is higher.

Because of lack of collateral, farmers with small land sizes may be willing to pay a higher interest rate (since theoretically, interest rate and collateral act as substitutes in terms of expected return). However, accepting a higher interest rate may be a signal for accepting higher risks: they accept a higher rate because their probability of repaying the loan is low. It is the adverse selection effect identified by Stiglitz and Weiss (1981). The lender thus does not accept the transaction and the credit market is characterised by rationing⁵.

Following Feder *et al.* (1990), the following definition is used: a farmer has access to credit (or is non-constrained) if it got a loan or did not get credit because it did not need it. Farmers with no access to credit are those who did not get credit for the following reasons: credit was not available or collateral was missing. Farmers who did not get credit because they said credit is too costly are classified as non-constrained. In fact, they did not get credit not because of the credit supply, but because at that price their demand for credit was non-existent. Note that this definition implies that the received loan amount is equal to the amount asked by the farmer, since farmers who got a loan (whichever the amount) are classified as having access to credit.

4.2. Estimation issue

The credit constraint is introduced using a variable describing the farmer's "general" assessment of access to credit over her lifetime⁶. However, it is not possible to introduce the variable directly

⁵ There is another reason why lenders may not increase the interest rate in the case of excess demand for loans: Stiglitz and Weiss (1981) show that higher interest rate induce borrowers to undertake riskier projects, for which the return to the lender is lower: it is the incentive mechanism.

⁶ The question is phrased as follows: "have you obtained long term credit for your dairy activity?" if not, "why not?"

since there may be some unobserved variables that influence both the adoption decision and the farmer's access to credit status (i). Following Kochar (1997), unobserved variables are twofold: the first set of variables deals with some farmer's characteristics, e.g. the farmer's capacities in enterprise management; the second set concerns the differential farmers' access to some institutions (e.g. co-operatives dealing with cash crops) that may influence both the adoption decision and the access to credit. Because of these unobserved variables, the access to credit status cannot be considered exogenous in the adoption equation since the covariance between the access to credit variable and the residuals of the adoption equation may not be equal to zero. Therefore, the method of instrumental variables is used to predict the variable credit based on variables that are pre-defined to the adoption decision as showed in equation (8):

$$(8) \quad i_i = Z_{i,10} \cdot \alpha + u_i$$

where $Z_{i,10}$ represents the vector of pre-defined variables. The variables $Z_{i,10}$ are evaluated at the time of establishment because they should not be correlated with the residuals of the equation (6) to be considered as instruments.

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.

The variables $Z_{i,10}$ that are assumed to explain the farmer's access to credit are some household characteristics: household head's 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 is the ethnic group membership: a dummy variable is thus introduced for households from the same ethnic group 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 country⁷. Finally, since collateral is required to obtain a loan (either from the co-operative 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. those with large land sizes. The variable introduced indicates whether household's land size is higher than the average

⁷ Raturi and Swamy (1999) show that ethnic differentials in credit market outcomes may not reflect discrimination. In the case of Zimbabwe, the authors show that black- owned firms are more credit constrained because they are more likely to ask for a loan (maybe because they have less "connections"). The credit outcome is thus a higher proportion of black- owned firms to be denied a loan.

land size in the corresponding agro-ecological zone. Annex 2 details the computation of the variable.

As explained in section 2.1, holding a land title deeds is decisive to get a loan from AFC. It would have been relevant to introduce this information among the determinants of access to credit but the variable is not available.

For loan availability, three variables are identified. Since some of the state-provided loans are channelled to farmers through co-operatives, availability of a dairy co-operative in the neighbourhood is expected to improve access to credit. The variable is evaluated at the time of the farm establishment, as required by equation (8).

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 as shown in annex 1. The variable is evaluated at the time of the farm establishment, as required by equation (8).

Finally, the overall credit supply in the area is captured by the percentage of farmers in the sublocation who got a credit. The variable is calculated using the survey data. A higher credit supply is hypothesised to increase the individual access to credit and the variable is thus introduced among the explanatory variables.

4.3. Econometric analysis

Equation (8) presents the equation to be estimated. The error terms u_i are assumed to follow a logistic distribution and the model is estimated using the method of maximum likelihood. The likelihood function is written as:

$$L = \prod_{i_i=1} F(z'Z_{i,t0}) \cdot \prod_{i_i=0} (1 - F(z'Z_{i,t0}))$$

where $F(z'Z_{i,t0}) = \Lambda(z'Z_{i,t0}) = \frac{\exp(z'Z_{i,t0})}{1 + \exp(z'Z_{i,t0})}$ is the logistic cumulative distribution

function, $i_i=1$ for the farmers with access to credit and $i_i=0$ for the farmers without access to credit.

The log-likelihood to be maximised is written as:

$$(9) \ln L = \sum_{i_i=1} \ln F(z'Z_{i,t0}) + \sum_{i_i=0} \ln(1 - F(z'Z_{i,t0}))$$

Two estimations are conducted on the available data (884 dairy farmers). The first one derives directly from equation (9) and the results are presented in annex 2. However, this estimation does

not control for the sampling design and results may not be consistent (Deaton 1997). A second estimation is then run, which introduces weights and controls for the sampling design (stratification and clustering): results are presented in table 2 below. The model is estimated using a "pseudo- maximum- likelihood" method. The vector of unknown coefficients α is the solution of the weighted sample estimating equation:

$$(10) G(\alpha) = \sum_{s=1}^S \sum_{c=1}^C \sum_i w_{sci} \cdot D(\alpha; i_i, Z_{i,t0})$$

where $D(\alpha; i_i, Z_{i,t0}) = \frac{\partial l}{\partial \alpha}$, $l(\alpha; i_i, Z_{i,t0})$ is the "associated log- likelihood", w_{sci} denote the sample weights, $s=1 \dots S$ is the number of strata, $c=1 \dots C$ is the number of clusters (or primary sampling units) (Statacorp 1999).

Table 2: Logistic regression of access to credit

The dependent variable is equal to 1 if the household has access to credit, 0 otherwise		
Explanatory variables	Odds ratio	P> t
<i>Household characteristics</i>		
- sex of the household head (1 if man)	0,805	0,371
- education level (years)	1,018	0,397
- age of the household head when established	1,010	0,246
- 1 if from the same ethnic group than the ruling party	1,408	0,182
- 1 if "large" land acreage when established	1,842***	0,005
<i>Loan availability</i>		
- 1 if dairy co-operative in the neighbourhood when established	0,863	0,548
- dummy for AFC loans	0,974	0,913
- % of farmers who received a loan in the area	2,052***	0,005
Number of observations	898	
Percent correct predictions: access to credit	64.05	
Percent correct predictions: no access to credit	53.30	
Percent overall correct predictions	61.69	

*** indicates that the odds ratio is statistically significant at 1%.

The variables land size and the indicator of credit supply in the area are significant and with the expected sign. The variable describing loan availability by AFC is not significant, maybe due to the poor quality of this variable (dummy variable). The overall percentage of correctly predicted observations is 61.7%. Predicted probabilities of access to credit are then computed and introduced as explanatory variable in the adoption equation.

Econometric results obtained by the two methods do not differ in terms of the overall fit of the estimation. However, results of the "classical" logistic estimation show that two other variables are significant: the age of the household head and whether the household is of the same ethnic group than the ruling party. The coefficients of these two variables are positive:

older farmers have a higher access to credit, maybe reflecting their "good" reputation. And as expected, farmers from the same ethnic group than the ruling party benefit from a better access to credit.

5. The decision to adopt grade cattle technology: empirical analysis

The theoretical model presented in section 3.3. has identified the determinants of the decision to adopt grade cattle technology. In this section, the model is estimated and the hypothesis that access to credit facilitates adoption is tested. The first section presents the link between the theoretical model and the empirical setting, while the second section shows the estimation results. The last section concludes.

5.1. From the modelling to the empirical analysis

Table 1 presented the categories of variables that the theoretical model has identified as determinants of adoption. In this section, the description of the variables introduced in the empirical analysis is presented. Before detailing the variables computation, the first sub-section presents the estimation method.

5.1.1. The estimation method

Equation (6) shows that the farmer's decision to rear grade cattle at time t of the survey C_t depends on the determinants in the following way:

$$(6) \quad C_t^* = C_t(i_t, p_{c,t}, \overline{H}_t, p_{m,t}, TC_m, w_t^m, w_t^w, s, L_t^m, L_t^w, p_{j,t}, p_{v,t}, Z_t^h, Z_{f,t}^r, Z_{c,t}^r, \sigma^2) \\ = C_t^*(x_t)$$

The exogenous variables x_t explain the decision to keep grade cattle at t and thus should be evaluated at that time. However, it turns out that some variables cannot be considered purely exogenous and will be evaluated at the time of the farm establishment as explained below.

The next step is to define $D_{i,t}$ as equal to 1 if the farmer i has grade cattle at the time t , of the survey (the farmer is an adopter), 0 if not.

More formally:

$$(11) \quad D_{i,t} = 1 \text{ if } C_{i,t}^* > 0 \\ D_{i,t} = 0 \text{ if } C_{i,t}^* \leq 0$$

Assuming a linear form in its arguments, $C_{i,t}^*$ can be written as:

$C_{i,t}^* = \phi' \cdot X_{i,t} + \varepsilon_{i,t}$ where ϕ' is a vector of unknown parameters to be estimated and $\varepsilon_{i,t}$ follows a logistic distribution. The econometric model to be used is thus a logistic formulation. Two estimation methods are used and are similar to those used for the estimation of the access to credit status. They are exposed in section 4.3.

5.1.2. The variables computation

This section details the variables of table 1. Note that the variable of access to credit has already been described in section 4. The predicted probabilities of access to credit are computed for both the cattle-owning farmers and the non cattle-owning farmers.

- Household characteristics

The household characteristics include characteristics of the household head and other household characteristics. Household head characteristics that are introduced in the estimation are the age, gender, education level (years of formal education) and ethnic group. Following equation (6), the variables are evaluated at the time of the survey.

The other household characteristics are the total land size and the availability of family labour. Total land size owned by the household cannot be considered purely exogenous in the equation (6) since it depends on past decisions about cattle production; in fact, savings from previous cattle activities may be used to buy some land. As a consequence, there are some unobservable variables affecting both the land size and the decision to keep cattle at t . To rule out the possibility of a bias, land size introduced in the equation is evaluated at the time of establishment t_0 , i.e. before dairy activities. More formally, there is no bias because $\text{Cov}(\overline{H_{i,t_0}}, \varepsilon_{i,t})=0$.

Time-series data on land size owned are available for the “other district survey” households but not for the “Kiambu survey” farmers, as explained in chapter 1. By consequence, the variable that is introduced for the Kiambu farmers is the land size at the time of the survey. It is thus assumed that no changes had occurred or that they were minor.

The availability of family labour is the total number of adults living on-farm. The variable is evaluated at the time of the survey t_t as described in equation (6). The second variable related to family labour is the proportion of female adults (over total number of adults) since the theoretical model has shown the importance of distinguishing men and women labour force. The variable is evaluated at the time of the survey.

The total number of household members living on farm may capture another effect: the availability of off- farm income. In fact, the higher the number of members, the higher the possibility for the household to have some off- farm income. Off- farm income is expected to have a positive effect on adoption since it may loosen the liquidity constraint. The variable number of adults on farm thus captures two effects: the “pure” theoretical effect of labour availability (positive effect) and the positive effect through off- farm income.

Note that the availability of off-farm income may be estimated using the available data. However, the adoption decision and the decision to get an off-farm job cannot be considered separately since the household takes these decisions simultaneously. The variable off-farm income is thus endogenous in the equation of adoption. It thus raises the same issue than the access to credit variable. However, there are no good instruments available that could predict the availability of off-farm income, as it was the case for the variable access to credit. In fact, the variables that could have been used are variables that are used directly in the adoption equation. The solution is then to introduce off-farm income indirectly, i.e. introduce in the adoption equation variables characterising the environment in terms of off-farm employment opportunities and variables illustrating the household’s ability to take off-farm employment. Variables characterising the environment in terms of off-farm employment opportunities are distances to urban centres while variables illustrating the household’s ability to take off-farm employment are number of adult members (and education level, but there are no information on the education level of the household’s members apart from the head). The variable "number of adults" and the distances variables thus capture the direct (theoretical effect) and the effect through the off- farm income.

- Prices and transaction costs

Milk price is an indicator of the profitability of the dairy enterprise. According to equation (6), the price is evaluated at the time of the survey. It is calculated as the average milk price paid to farmers at the cluster level; it thus reflects the farmers' decision for a specific market outlet. Milk markets are likely to be segmented in the surveyed area because of the poor road infrastructures. As shown in annex 4.1., the milk price for the adopters is statistically lower compared to the non-adopters' cluster price: this result can be explained by the fact that milk price is a decreasing function of the milk supply in a particular location. Since milk supply depends on the adoption decision, cluster milk price cannot be considered purely exogenous in the adoption equation. Because of the importance of this variable in the decision, two adoption equations are estimated: the first one evaluates milk price at the time of the survey (average by cluster); the second

equation evaluates the price at the year of the farm establishment (adjusted for the prevailing consumer price index) in order to exclude a possible endogeneity bias (in the same way than the land size variable). Details about the computation of the variable "milk price at the year of the farm establishment" are provided in annex 3.1.

In order to capture the possible effect of the 1992 liberalisation of the dairy sub- sector on the farmers' incentives to adopt, a dummy variable is introduced. The variable is equal to 1 if the household established the farm after 1992, 0 if before.

Transaction costs are introduced through distances to urban centres. Because data on distances were not collected the same way for the two surveys, adjustments were necessary. They are explained in annex 3.2. Variables introduced are distances to Nairobi for households in Kiambu district (Kiambu being in the neighbourhood of Nairobi) and the mean to the two nearest urban centres for the other households. Total distance is differentiated by road types, between all-weather roads and dry-weather roads.

According to the theoretical model, the wage rate variable is an indicator of the cost of hired labour. However, because availability of off-farm income could not be introduced separately, the wage rate accounts for two effects: effect through cost of hired labour ("pure" theoretical effect, negative effect) and effect through employment opportunities (negative effect since a higher wage rate induces households to take an off-farm job rather than specialising on the farm, i.e. adopting grade cattle technology). The variable that is introduced is the mean wage rate at the sublocation level, in Ksh per day. This variable is evaluated at the time of the survey as required by equation (6).

The other prices are not introduced in the regression because they do not vary across farmers.

- Area characteristics

Area characteristics include variables specific to dairying and variables for both dairying and crop activities. Variables specific to dairying are risks of animal disease, dairy co-operative availability and artificial insemination availability. Risks of animal disease are introduced through a dummy variable indicating the presence of ticks as described in chapter 1. Dairy co-operative availability indicates the presence in the sublocation of a dairy co-operative. For the availability of artificial insemination services, the variable indicates the extent of artificial insemination services

in the sublocation; more precisely, it is the percentage of surveyed households in that sublocation for which artificial insemination services are available (if they use it or not).

Other variables, both dairy-specific and for crop activities, are introduced. Two variables are introduced, the annual precipitation over potential evapo-transpiration ratio and minimum temperature. These variables are presented in chapter 1 and indicate the general agro-climatic conditions and are evaluated at the household level. This allows an adequate control of the climatic conditions that is more precise than area dummy variables.

Finally, a dummy variable differentiating the two survey areas (1 for “other districts” farmers, 0 for “Kiambu” farmers) is introduced in order to control for the difference in the way some explanatory variables have been calculated (land size and distances).

5.2. Estimation

A weighted logistic estimation is conducted that takes into account the sample design (in the same way as the regression for access to credit). For comparison, an un-weighted regression is conducted (without controlling for the sample design). Results of the weighted regression are presented in table 3 below; the results of the un-weighted regression are in annex 4. The variable “milk price” that is introduced is the price evaluated the year of the farm establishment. The table in annex 4 presents also the results of the estimation with the variable “milk price” evaluated at the time of the survey, as explained in 5.1.2.

Results are consistent across the two estimation methods; findings can thus be considered reliable. When milk price at the time of the survey is introduced (instead of price at the farm establishment), the dairy co-operative variable is no more statistically significant. This result is expected since milk price at the time of the survey introduces implicitly the choice of outlets in the neighbourhood (the variable is calculated at the sublocation level): the possible influence of a dairy co-operative in the neighbourhood is then captured by the milk price variable.

Table 3: Logistic regression of the decision to adopt grade cattle technology

The dependent variable is equal to 1 if the household is an adopter, 0 otherwise

Variables	Model variables	Odds Ratio	T-statistics	Significance
<i>Access to credit</i>				
- estimated probability of access to credit	i	1,031	2,698	0,008
<i>Household & household head characteristics</i>				
- age of the household head	Z^b	0,992	-1,005	0,318
- sex of the household head	Z^b	1,339	1,156	0,251
- education level (years)	Z^b	1,073	2,891	0,005
- 1 if kikuyu	Z^b	4,158	4,817	0,000
- land acreage when established	\bar{H}	1,046	3,603	0,001
- number of adults	L^m, L^w	1,032	0,844	0,401
- proportion of female adults	L^m, L^w	1,513	0,864	0,390
<i>Prices and transaction costs</i>				
- adjusted milk price [♦]	p_m	3,160	1,593	0,115
- dummy variable for liberalisation	p_m, Z_c	0,528	-2,155	0,034
- distance on all-weather roads	TC_m	0,985	-1,818	0,073
- distance on dry-weather roads	TC_m	1,012	0,288	0,774
- Wage rate	w	0,997	-0,949	0,346
<i>Area characteristics</i>				
- dairy co-operative availability	TC_m, Z_c^r	1,525	1,993	0,050
- extent of A.I. availability	Z_c^r	1,993	2,300	0,024
- 1 if it is a tick-infected area	Z_c^r	0,537	-1,806	0,075
- annual PPE	Z_c^r, Z^r	1,079	5,493	0,000
- minimum temperature	Z_c^r, Z_f^r	1,342	4,078	0,000
- 1 if other districts, 0 if Kiambu	<i>control</i>	1,165	2,570	0,012
Number of observations	1254			
Percent correct predictions: adopters	78.34			
Percent correct predictions: non adopters	72.87			
Percent overall correct predictions	76.95			

[♦] year of farm establishment

5.3. Analysis of the results

Goodness-of-fit indicators are satisfactory, with 78.34% of correctly predicted adopters and 72.87% of correctly predicted non-adopters. The overall percentage of correctly predicted households is 76.95%.

The results are reported using odd ratios (e^{ϕ} instead of ϕ). An odd ratio higher than 1 indicates that the variable has a positive effect on the adoption decision; if the odd ratio is below 1, the effect of the variable on the adoption decision is negative.

Results show that access to credit has a positive and significant effect on the adoption decision: the hypothesis that access to credit facilitates adoption cannot be rejected. In order to quantify

the effect of access to credit on the probability of adoption, marginal effects are calculated as follows (Greene, p. 874):

$$(12) \frac{\partial E[y|X]}{\partial X} = \Lambda(\varphi.X).[1 - \Lambda(\varphi.X)].\varphi$$

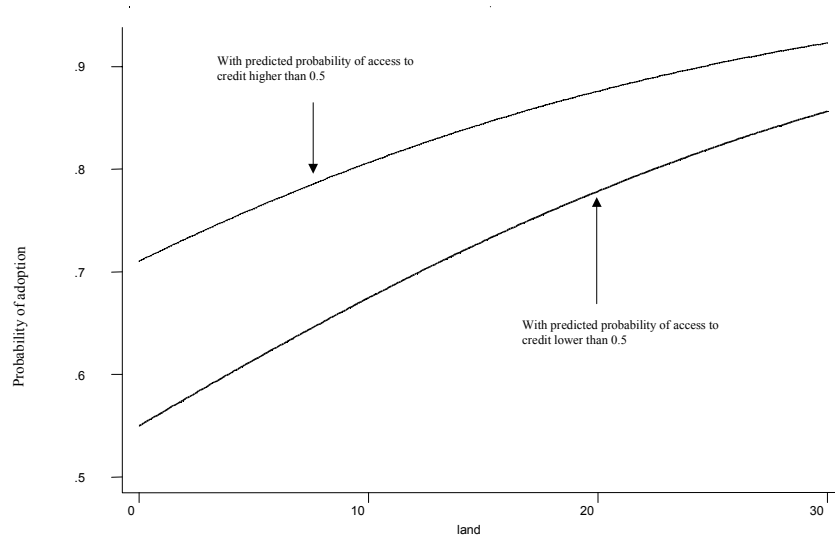
where $\Lambda(\varphi.X) = \frac{\exp(\varphi.X)}{1 + \exp(\varphi.X)}$ is the cumulative logistic distribution function.

There are two ways to calculate the marginal effects. The first method evaluates the marginal effects at the mean of the explanatory variables; in the second method, the marginal effects are evaluated as the means of the individual effects. Following Greene, the second method is preferred. Results show that increasing access to credit by 10% increases the adoption probability by 4.8%. The effect is thus not negligible.

Moreover, when distinguishing farmers by land class, calculations show that the marginal effect of increasing credit access is significantly higher for farmers with smaller land holdings. In fact, increasing credit access by 10% for farmers with less than 2 acres increases their adoption probability by 5.3% while the adoption probability increases only by 4.4% for farmers with more than 2 acres. The difference is statistically significant at 5%. Credit facilities should then be targeted to farmers with limited land sizes in order to generate the higher effect on adoption of grade cattle technology.

Predicted probabilities of adoption can also be graphed. Graph 1 presents the predicted probabilities of adoption in function of land size, by access to credit status. Because two groups of farmers are needed (farmers with access to credit *versus* farmers without), the (continuous) credit variable is transformed into a dummy variable. Farmers with (without) access to credit are defined in this case as farmers for which the predicted probability of having access to credit is higher (lower) than 0.5. The model is then re-estimated; the estimation does not differ from the other estimations and is presented in annex 4.3. The predicted probabilities are then calculated using equation (12), by access to credit status and function of the land size variable.

Graph 1: Predicted probability of adoption, by access to credit and function of land size



The graph confirms that farmers with access to credit have a higher probability to adopt. However, the difference in predicted probabilities of adoption between the two categories of farmers is almost the same whichever the land size. In particular, credit may have a lower effect for farmers with large land size since this category of farmers are more able to finance the entry cost into dairying with own savings. Note that at very high levels of land size, the graph suggests that the difference in the adoption probabilities between the two categories of farmers is slightly lower; however, there are very few farmers (less than 5%) with land sizes higher than 20 acres and this result cannot be used to draw a general conclusion.

Predicted probabilities of adoption are computed by sex of the household head to analyse the effect of credit between female-headed and male-headed households (using the estimation with the continuous credit constraint variable). The marginal effect of 10% more access to credit on the adoption probability is evaluated at 5.1% for the female-headed households *versus* 4.7% for the male-headed households (the difference is statistically different at 5%). Credit facilities if targeted to female-headed households thus would have a higher effect than if not targeted.

Some household's head characteristics are significant on the probability of adoption. In fact, the level of formal education has a positive effect on adoption: four more years of formal education (e.g. from primary school to secondary school) increase the household's probability of adoption by 4.5%.

Kikuyu households have a higher probability of adoption also. The marginal effect for dummies can be assessed in two ways that are described in annex 4.4. When using the exact method, Kikuyu households are more likely to adopt (compared to the other ethnic groups) by 26.6%. The effect is thus large, reflecting Kikuyus' tradition to keep cattle and favourable agro- climatic conditions of the Kikuyu traditional settlement areas. This result can be related to the findings of Nicholson *et al.* (1998) in an adoption study of grade cattle in the Coastal Kenya: migrants have a higher probability of adoption and this result is explained by their previous exposure to the grade cattle technology.

Another household characteristic that is significant is the total land acreage: the effect is positive as expected since more land allows the household to produce more fodder. The marginal effect is however quite limited: one acre more (e.g. shifting from the first to the second quartile in terms of land size) increases the probability of adoption by only 0.7%. In their study in Coastal Kenya, Nicholson *et al.* find no relationship between the amount of land owned and the adoption decision.

Had the credit variable not been introduced in the estimation, the effect of land would have captured its "direct" effect and the effect through higher access to credit. When re- estimating the equation without introducing the credit variable among the determinants of adoption, the marginal effect of land is overestimated by almost 0.6%; the effect of land is then evaluated at 1.3%. The difference is small but statistically significant (at 1%); this result highlights the importance of introducing explicitly a measure of the farmer's access to credit in the adoption equation.

Surprisingly, the family labour availability variables (total family labour and percentage of female members) are not significant.

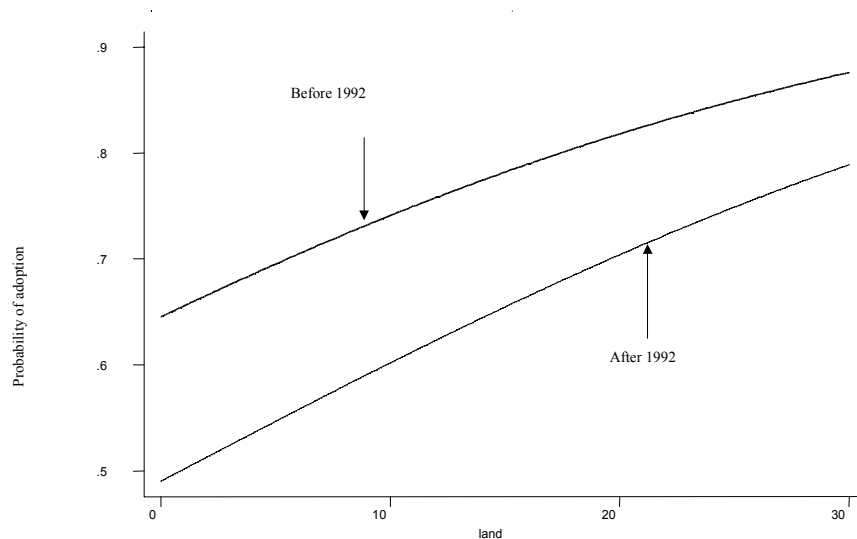
Milk price when evaluated at the year of the farm establishment is not significant. On the other hand, when introducing current milk price (annex 4.2), the effect is negative and statistically significant: higher milk prices discourage the adoption of grade cattle technology. This unexpected result is explained by the endogeneity of the variable in the adoption equation, as

explained in section 5.1.2. Higher milk prices reflect high milk supply in the area and thus past adoption decisions.

The dummy variable indicating liberalisation is significant, showing that farmers who established after the liberalisation have a lower probability to adopt. This result may reflect the fact that these households, who are newly formed, have not yet got the time to adopt. The marginal effect of the liberalisation is assessed using the method described when evaluating the effect of being Kikuyu. Farmers who established their farms after the 1992 liberalisation of the dairy sector have 10.8% less chance to enter into dairy farming; the effect is thus large, especially when compared to the effect of land size on adoption.

It may be hypothesised that the effect of the liberalisation affected more negatively the "small" farmers, compared to the households with large land size. Graph 2 explores this possibility by plotting the predicted probabilities of adoption by farmers who established before and after the 1992 liberalisation, function of land size.

Graph 2: Predicted probability of adoption, before and after the liberalisation and function of land size



The same conclusion can be drawn than in the case of credit: it cannot be concluded that the liberalisation affected differently farmers, when classified by their land holdings.

The transaction cost variable, namely the distance on all-weather roads has a significant and negative effect: the further the farm from urban centres where the demand is, the lower the probability of adoption. This is consistent with the literature on transaction costs but different from the results of Nicholson *et al.* who found no relationship between distance to roads and the adoption of grade cattle in Coastal Kenya. The explanation given by the authors is that the studied area is characterised by excess demand for milk, hence milk sales are mainly local ("over-the-fence") and distances to the market are less important for milk marketing.

In this analysis, the calculation of marginal effects shows that a farmer situated 10 kilometres further from the urban centres has a probability of adoption lower by approximately 2.4% (compared to the farmer situated closer). The effect is thus relatively small.

As for the area characteristics, the availability of artificial insemination services fosters adoption of grade cattle as expected. Farmers for which artificial insemination services are available have an adoption probability higher by 11.0% compared to farmers living in areas not covered by these services. And the risks of animal disease influence the adoption negatively, as expected: the marginal effect is relatively comparable to the effect of artificial insemination services since farmers in areas infected by ticks have 9.4% less chance to adopt. The last area characteristic is the dairy co-operative availability: farmers with a co-operative in the neighbourhood adopt more by 6.8% compared to farmers without co-operative in the area.

Other services needed for dairy farming are veterinary and extension services: availability of these services cannot be introduced simultaneously with the availability of artificial insemination services because of the in-built collinearity between the variables. In fact, services are often offered as a package but it may be interesting to evaluate the individual effect of the veterinary and extension services on the adoption decision. Two other regressions are then estimated; a variable describing the availability of veterinary services is introduced in the first regression (instead of the availability of artificial insemination services). The second regression introduces the availability of extension services. Marginal effects of the availability of these two other services are comparable to the effect of artificial insemination services. In fact, farmers for which veterinary (extension) services are available are more likely to adopt by 16.7% (14.9%). Note that the marginal effect of the availability of veterinary services is statistically significant (at 1%) and higher to the effects derived from the two other services.

Finally, the control for the climatic conditions proved to be relevant since the two variables (PPE and minimum temperature) are significant and with the expected sign. The major climatic indicator (PPE) ranges from 46 to 105: 10 units of the variable increases the probability of adoption by 12.1%.

6. Conclusions of chapter 3

The analysis conducted in this chapter aims at identifying the constraints and opportunities of adoption of grade cattle technology by Kenyan smallholders. The focus is on whether better access to credit is likely to facilitate the entry into dairying. Results of the empirical analysis show that this hypothesis cannot be rejected: farmers with higher access to credit have a higher probability of adoption, *ceteris paribus*. Moreover, farmers with small land sizes seem to be more credit constrained: increasing access to credit by 10% for "small farmers" raises the likelihood of adoption by 5.3% *versus* 4.4% for "large farmers". Credit programs should thus be targeted towards farmers with limited land size in order to generate the maximum effect. A similar conclusion can be drawn for female-headed households: the effect of access to credit on the adoption is higher for female-headed households when compared to male-headed households.

Another possible policy intervention deals with the availability of services offered to farmers: controlling for the other determinants, farmers for which artificial insemination services are available are more likely to keep grade cattle by 11%. The calculation of marginal effects for the other services (veterinary and extension services) present similar results. Moreover, the availability of a dairy co-operative in the neighbourhood, by offering a reliable outlet to the smallholders' milk production, increases the probability of adoption by almost 7%. These results highlight the importance of providing accessible services to the smallholders population if adoption trends are to be maintained. A similar conclusion is reached when analysing the effect of the 1992 liberalisation of the dairy sub-sector. The liberalisation resulted in higher farm-gate milk prices but at the same time the government provision of services was progressively lifted. Econometric results show that the adoption likelihood for farmers who established their farms after 1992 is lowered by more than 10%. While this result may reflect the fact that farmers had not yet got the time to adopt (and not the effect of the liberalisation), the result is informative and suggests that the liberalisation has not speeded up the adoption rate as it could have been assumed. This result is consistent with the analysis of Omore *et al.* (1999) who observe that the private sector has yet

to fill the gap in the delivery of livestock services following the withdrawal of government services; in these circumstances, farmers are less induced to enter into dairy farming.

A third policy intervention concerns the education level: because education eases the farmer's training in dairying, it is not surprising to observe that more educated household heads have a higher probability to adopt. Using the econometric results, it can be shown that a farmer with a secondary education level is more likely to adopt the grade cattle technology by 4.5% compared to a farmer with a primary education level.

Finally land size has a limited effect on adoption when controlling for the other determinants: one more acre of land increases the adoption probability by only 0.7%. When recalling that the surveyed area is characterised by relatively well- developed fodder markets and the possibility of road grass grazing, this result is not unexpected: not owning land to grow fodder does not seem to be a major constraint in the adoption of grade cattle technology. Note however that owning land is crucial when applying for a loan: the results of table 2 show that farmers with a "large" land size are more likely to have access to credit by 13.7%. The effect through access to credit is thus much higher than the direct effect⁸. Moreover, owning land is crucial also to accumulate savings to finance the entry cost as it will be apparent in the next chapter. In fact, the model tested in this chapter is fundamentally static and the flows of savings and investments are not taken into consideration. The role of time could not be introduced and this is a serious limitation in the model. The next chapter introduces explicitly time in the analysis, thus allowing a more relevant test of the hypotheses that the constraints identified in this chapter are those at work.

⁸ A similar conclusion is drawn by Boahene *et al.* (1999) in a study of the adoption of hybrid cocoa in Ghana: bank loans have a significant impact on adoption but not access to land.

Annexes

Annex 1: Agricultural Finance Corporation – Interest charged on loans and amount of loans for the “dairy cattle” activities.

Year	Interest rate	K ₧'000
		Amount of Loans
72	n/a	140,240
73	n/a	175,905
74	n/a	255,645
75	n/a	69,730
76	9	192,825
77	9	212,315
78	9.5	303,350
79	9.5	410,700
80	10	359,145
81	13	792,676
82	13	877,250
83	13	1,905,000
84	13	954,159
85	13	583,143
86	13	11,180
87	13	8,218
88	13	12,202
89	13	2,414
90	13	1,028
91	13	1,439
92	13	1,807
93	20	1,345
94	20	2,205
95	20	n/a
96	20	n/a
97	20	n/a
98	20	n/a

Sources: Statistical Abstract, Republic of Kenya (various issues)

Notes:

1. Interest rates are interest rates for “other activities” (the other categories being land purchase and seasonal crop loan).
2. Smallholder credit included as from 1982.

Annex 2: Access to credit: results from the empirical analysis

2.1. Computation of the variable "land size"

For the "other districts" households, two elements are taken into consideration: the land size when the farmer established the farm and the agro-ecological zone (AEZ) where it is located. A variable indicating in which group – year/AEZ – is formed. The year of establishment is categorised by decade: 1 if before 1960, 2 if from 1960 to 1970, 3 if from 1970 to 1980, 4 from 1980 to 1990 and 5 if 1990 or after. There are 4 AEZ (Nairobi, low highlands, upper highlands and upper midlands). The number of combinations is 17 and the mean land size by combinations is then used as the cut-off. Each household is then assigned a value 1 if its land size when established is equal or higher than the mean land size in the corresponding AEZ/decade. For the "Kiambu" households, there are no data on the land size at establishment. By consequence, the mean land size is calculated by AEZ without considering the year of establishment. Each household is then assigned a value 1 if its land size is equal or higher than the mean land size in the corresponding AEZ.

2.2. Some statistical information

2.2.1. Access to credit

Access to credit	Number of households (percentage)
Access to credit	530 (59.95)
No access to credit	354 (40.05)
Total	884 (100)

2.2.2. Statistical analysis: mean of the variables by type of household

Variables	Access to credit	No access to credit	% difference-significativity
<i>Household characteristics</i>			
- sex of the household head (1 if man)	0.74	0.78	-5.41
- education level (years)	8.08	8.06	0.25
- age of the household head when established	31.14	30.28	2.76
- 1 if from the same ethnic group than the ruling party	0.47	0.36	23.40***
- 1 if "large" land acreage when established	0.40	0.28	30.00***
<i>Loan availability</i>			
- 1 if dairy co-operative in the neighbourhood when established	0.21	0.23	-9.52
- dummy for AFC loans	0.26	0.34	-30.77***
- % of farmers who received a loan in the area	0.42	0.28	33.33***

*** indicates that the difference is statistically significant at 1%.

2.3 Econometric analysis:

Logistic regression of the access to credit status, un-weighted regression and no control for the sample design

The dependent variable is equal to 1 if the household has access to credit, 0 otherwise		
Explanatory variables	Odds ratio	P> z
<i>Household characteristics</i>		
- sex of the household head (1 if man)	0,779	0,143
- education level (years)	1,020	0,301
- age of the household head when established	1,013***	0,074
- 1 if from the same ethnic group than the ruling party	1,509**	0,011
- 1 if “large” land acreage when established	1,686***	0,001
<i>Loan availability</i>		
- 1 if dairy co-operative in the neighbourhood when established	0,879	0,447
- dummy for AFC loans	0,940	0,725
- % of farmers who received a loan in the area	1,911***	0,000
Number of observations	898	
Percent correct predictions: access to credit	64.11	
Percent correct predictions: no access to credit	53.89	
Percent overall correct predictions	61.92	

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

Annex 3: Construction of the variables for the estimation of the adoption decision

3.1. Milk price

The variable that is introduced is the KCC milk price for the year of establishment of the farm, adjusted for the consumer price index. These data are extracted from “Statistical Abstract” published by the Republic of Kenya (various issues). KCC price is an average price paid by Kenya Co-operative Creameries (weighted average for the three groups of milk designated by KCC as “quota milk”, “contract” and “milk for separation”). This price is usually not the farm-gate price (although some farmers deliver milk directly to KCC), since most of the milk delivered to KCC comes from dairy co-operatives. Members of the co-operatives (i.e. farmers) are then paid this price minus a certain percentage levied by the co-operative to cover for its functioning costs. Using KCC price gives consistent time-series data, contrary to prices at the farm-gate for which data are scanty. Moreover, farm-gate milk prices are not independent of the farmer’s choice of market outlets. In fact, informal markets fetch higher price while co-operatives (formal outlet) compensate the lower price paid by providing some services (e.g. credit and artificial insemination services). The choice of the market outlet, which is an endogenous choice at the farmer level, determines in a certain extent the milk price. On the contrary, pan-national KCC prices can be considered exogenous at the farmer level. Howard and McDonald (1988) have showed that the price paid by KCC (regulated market) influences positively the price paid on the informal (unregulated) milk market: KCC milk prices can thus be considered appropriate to approximate the average farm-gate milk price over the years.

3.2 Transaction costs variables

Transaction costs variables are introduced through distances. Because data on distances were not collected the same way for the “other districts” farmers and for the “Kiambu” farmers, adjustments were necessary.

As explained in chapter 1, data on distances for the “other districts” farmers are available for three road types, i.e. all-weather roads- loose surface, all-weather roads- bound surface and dry-weather roads. On the other hand, distances for the “Kiambu” farmers that are available are

survey data only. It is then not possible to calculate the distance by the three road types. The survey data allow approximating the distance from the farm to Nairobi by two road types, i.e. by all-weather road (without distinction between loose and bound surface) and dry-weather road. Distance from the farm to Nairobi by all-weather road is approximated by the difference between total distance to Nairobi and “a road open to vehicles all year”. The same distance by dry-weather road is approximated by the difference between the distance to “a road open to vehicles all year” and the distance to “a seasonally passable road”.

Since distances for the “Kiambu” farmers could only be differentiated by two road types, the two distances on all-weather roads (loose and bound surfaces) for the “other districts” farmers were summed. The distances that are introduced are distances to Nairobi for the “Kiambu” farmers (Kiambu district being in the neighbourhood of Nairobi) and to the two nearest urban centres for the “other districts” farmers (since the other districts are further away from Nairobi, the effect of Nairobi market is lower).

Annex 4: Empirical analysis of the decision to adopt grade cattle technology

4.1. Statistical analysis: Variables means, by adoption status

Variables	Mean for Adopters	Mean for Non-Adopters	% Difference and significance
<u>Number of observations</u>	819	435	
<u>Access to credit</u>			
- 1 if the farmer has access to credit, 0 otherwise (observed value)	0.610	0.541	11.34
- Estimated probability of access to credit (*100)	60.799	54.435	10.47**
<u>Household & household characteristics</u>			
- Age of the household head	50.700	49.046	3.26**
- Sex of the household head	0.765	0.692	9.54**
- Education level (years of formal education)	8.278	7.149	13.63**
- 1 if kikuyu, 0 otherwise	0.901	0.632	29.86**
- Land acreage when established	6.103	4.326	29.13**
- Number of adults in the household	3.669	3.522	4.00
- Proportion of female adults	0.522	0.522	0.06
<u>Prices and transaction costs</u>			
- Adjusted milk price (year of farm establishment)	0.849	0.828	2.41**
- Milk price at the time of the survey (sublocation level)	14.863	18.860	-26.89**
- Wage rate (sublocation level)	94.123	94.941	-0.87
- Distance on all-weather roads (km)	34.054	34.038	0.05
- Distance on dry-weather roads (km)	2.755	2.807	-1.89
<u>Area characteristics</u>			
- 1 if there is a dairy co-operative in the sublocation	0.512	0.294	42.48**
- Percentage of farmers in the sublocation for which AI services are available	0.371	0.235	36.51**
- 1 if it is a tick-infected area, 0 otherwise	0.803	0.862	-7.40**
- Annual PPE	78.808	67.115	14.84**
- Minimum temperature	9.211	9.499	-3.12**

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