Parallel to the provision of veterinary services, the Kenyan government has run artificial insemination programs: artificial insemination was widely available to Kenyan smallholders at a subsidised cost. The current progressive removal of these programs, because of government expenditure cuts, can be seen as a threat to the development of the dairy sector since smallholders face difficulties to find high- grade semen at an "affordable" price in the neighbourhood of their farm. Some farmers use then bulls; but this option has many drawbacks: possible consanguinity and transmission of genetic diseases. In some areas, the private sector emerged after the removal of the government provision of services; however, the movement is concentrated in some high-potential area and the price is higher than farmers used to pay, which discourages them from choosing this option. Finally, dairy co-operatives have a role to play in the provision of services: Owango *et al.* (1998) show that co-operatives in three districts in the neighbourhood of Nairobi (Kiambu, Murang'a and Thika) have increased the provision of artificial insemination services and livestock feed sales following the 1992 milk marketing liberalisation. However, the substitution between government and co-operative provision of services may not occur in areas more distant to urban centres. In fact, the authors show that real prices paid to farmers fell following the liberalisation in the areas removed from the urban centres; co-operatives in these areas now face financial difficulties that may prevent them from offering artificial insemination services to their members. Moreover, the private sector may be unwilling to start operating in more remote areas because of higher costs and relatively lower cattle density.

4.2.3 Land availability for fodder

The economic literature identifies farm size as a major determinant of adoption of agricultural innovations in Developing Countries (Feder *et al.* 1985). Depending on the particular circumstances, this variable represents different factors:

- If the technology is not scale-neutral because of fixed costs of implementation, there is a direct positive relationship between farm size and the adoption level;
- If the technology is scale-neutral but not resource-neutral, farm size is a proxy for credit availability. In that case, the positive relationship between farm size and the adoption level is less direct than in the first case.

Besides having less access to credit, farmers with limited land size have fewer opportunities to accumulate savings that could be used to finance the entry cost of the new technology, *ceteris paribus*. This raises the issue of the observed bias against small farmers who cannot take

advantage of the increasing profitability of innovation due to financial constraints. Only the richer are in a financial position to adopt the more profitable technology: this creates a viscous circle of poverty.

Moreover farm size is assumed to be positively correlated with the capacity to bear risks, access to scarce inputs and access to information. Since it is difficult to measure these variables, the farm size variable capture all the different effects.

In the case of dairy farming in Kenya, it has been shown that fodder availability is a major constraint to production, so presumably to dairy adoption. Pressure on land is high in some areas (because of population density) so access to land is expected to foster adoption.

4.3 Network externalities in milk marketing

Network externalities arise when there is a need for a public-good element, like a marketing infrastructure (Besley and Case 1993). Potential adopters care about how many individuals adopt, where they are located and when they adopt since a single adopter will find it difficult to market alone her new production. A "common" adoption is necessary to make the adoption sustainable. Often marketing infrastructures take the form of the creation of a co-operative which is in charge of not only the marketing, but also the collection of the production from the members and the control of the quality if necessary. A famous example is the "Anand Pattern" in India. In 1945, farmers of the village Anand organised a dairy co-operative in order to control the marketing of their milk production (Brumby and Gryseels 1986, Belavadi and Niyogi 1999).

In the case of dairy farming, the need for organising the milk collection and marketing is particularly relevant since (1) milk is highly perishable and needs to be sold daily, (2) farmers live in scattered homesteads and (3) levels of production per farmer are low so that collective action is needed. These points are now briefly detailed.

The organisation of the milk collection is crucial in order to minimise the risks of spoiling it. The time constraint is tight: for example, the time from milking to cooling should not exceed 3 hours, cooled milk should be processed within 24 hours and pasteurised milk should be processed within 12 hours after cooling (Government of Kenya 1997). And since milk is bulky, there are increasing returns to scale in transportation. Collective action to organise milk collection routes is necessary when dealing with scattered small-scale farmers. There are two main systems to collect milk (Ngigi 1995). In every case, the farmer is individually responsible for delivering

milk to the collection point. The first system is when farmers use collective churns but there is a risk of adulteration of milk with water since monitoring is difficult. The second system is when individual farmers contract directly with a transporter and use their own churns but this option is more costly.

When network externalities are present, co-ordination problems may arise since farmers may have "conflicting preferences about the technology [marketing channel] to co-ordinate" (Tirole 1989, p.405). In Kenya, dairy co-operatives were created in the mid-1950 (Ouma 1980) in order to organise the collection of the smallholders' milk. Milk is then delivered to KCC which started marketing milk from the smallholder co-operatives as early as the late 1950s. However, only a limited portion of the smallholder milk was marketed through this channel since much of it was sold locally through informal channels. In fact, a quota system introduced in 1954 gave smallholders little incentives to deliver milk to KCC. This system had a three-tier pricing structure, which offers premium prices to producers able to meet quotas during the dry season. As a consequence, smallholders were usually paid at the lower price scales. The fact that KCC did not have technical support programmes is an additional reason for the limited milk deliveries by smallholders to the formal system. As Jaffee (1993) noted, milk collection and financial matters were left to the co-operatives.

In 1958 the Kenya Dairy Board is created. Its principal mandate was to stabilise prices and to improve milk quality. But the Board relied heavily on KCC' s tax payments for its operating fund and KCC used the Board to restrict the activities of competitors. Other producers than KCC were progressively allowed to sell milk only in smallest townships and rural areas. Following the recommendations of a Dairy Working Plan, the quota system was abolished in 1971 and replaced by a system of uniform prices set by the government. At the same time, KCC were forced to buy all the milk delivered to its plants. It became the "buyer of the last resort" and as compensation, KCC was given a monopoly position in the processing and marketing of milk.

Following these changes and as a consequence of the guaranteed outlet by KCC, milk deliveries by smallholders increased. However, this system resulted in important physical and financial losses. In fact, milk price was fixed at the same level for the whole country, which was in opposition with the differential in the costs of producing and transporting milk. Moreover, the seasonality of the milk production was not taken into consideration since the same milk price was fixed throughout the year. Omiti *et al.* (1993) in a study of the marketed milk production in Kenya over the 1957- 1985 period conclude that the uniform price paid by KCC was set at a too

low level during the dry season (when compared to the production costs), thus discouraging milk deliveries. On the other hand, the price encouraged excess milk deliveries during the rainy season.

Milk prices paid by KCC did not keep up with the increase in the input prices; moreover the co-operative started delaying the payments of milk deliveries. Progressively, farmers and co-operatives started selling their milk on the informal market where the price had increased. In 1992, milk supply to KCC had fallen by 35% compared to the previous years. Because of the drought, Kenyan towns were experiencing milk shortages and the government was forced to announce the liberalisation of the milk market. KCC monopoly on processed milk marketing in urban areas was lifted and controls on the producer and consumer prices were removed. Private traders, co-operatives and large farms were then incited to buy, process and sell milk. Informal milk traders interpreted the liberalisation as acceptance of raw milk sales in urban areas and increased their activities (Staal and Shapiro). Currently, 20% of marketed milk is delivered to KCC and private processors and the remainder is sold as non- processed milk: direct sales to final consumers and sales to co-operatives, self- help groups and milk traders who act as intermediaries (Omore *et al.*).

5. The data collection

5.1 Organisation of the surveys

The data of two surveys conducted in Kenya are used in the empirical analyses of the next chapters. Both surveys are part of a collaborative study of the dairy sector conducted by the International Livestock Research Institute (ILRI) of Nairobi, the Kenyan Agricultural Research Institute (KARI) and the Kenyan Ministry of Agriculture (MoA).

The first survey covers Kiambu district, which lies in the north of Nairobi district. The survey was implemented in 1996 and covers 365 households, of which 340 had some agricultural activities at the time of the survey. The second survey covers a larger area that is more distant from Nairobi district: eight districts of Eastern, Central and Rift Valley Provinces were surveyed. A total of 1375 households were surveyed in 1998, of which 1042 had some agricultural activities at the time of the survey. The eight district surveyed in 1998 are Narok, Nairobi, Maragua, Murang'a, Nakuru, Nyandarua, Kirinyaga and Machakos. Annex 2 presents a map of the surveyed area.

For convenience in that follows, the survey conducted in Kiambu in 1996 is termed the "Kiambu survey" and the survey conducted in 1998 in the eight other districts is termed the "other districts survey". The author participated actively in the "other districts survey". Different tasks were realised in collaboration with the project's staff and other students: preparation of the questionnaire, calculation of the sample size, enumerators' training, supervision of field work during the survey, recording of farmers' geographical position, preparation of the feedback sessions with the surveyed farmers and data cleaning.

The empirical analyses of chapter 2, 3 and 5 use both datasets since the needed information to conduct these analyses are available from the two surveys. For the analysis conducted in chapter 4, time- series data on some household characteristics are needed; since the "Kiambu survey" did not collect such information, the analysis is based on the "other districts survey" dataset only. The questionnaires are published in the survey reports and are available from the author upon request. Study sites are grouped according to production potential and market access as shown in table 3:

Table 3: Surveyed sublocations, by potential

Agro-ecological potential	Level of market access	District(s)
High potential	High market access	Kiambu
	Medium market access	Kirinyaga, Murang'a/Maragua
	Low market access	Nyandarua (south)
Medium potential	High market access	Nairobi and Machakos
	Med. Market access	Nakuru
	Low market access	North Narok

5.2. Calculation of the sample size

For both surveys, the sampling method is a multistage sampling, in which the first stage units are the sublocations and the second ones the households. For the Kiambu survey, eight sublocations are randomly selected in each of the three agro- ecological zones (as defined by Jaetzold and Schmidt 1983). The number of households to be surveyed in each sublocation is then determined as a proportion of the total number of households in the sublocation obtained from the 1989 census figures (C.B.S. 1994).

At the first stage of the sampling, the probability to select a sublocation is not equal across the agro- ecological zones; weights are thus calculated as the inverse of the probability to select a

sublocation in each agro- ecological zone. At the second stage of the sampling (sampling of the number of households), the process is self- weighting (Kish 1965 and Kalton 1983).

For the other districts survey, the first step is to select randomly sublocations from the eight districts that constitute the population of reference. The selected sublocations are then grouped into stratification groups (or strata). Based on the agro-ecological zones described by Jaetzold and Schmidt and field knowledge, six major land use systems, namely coffee/dairy, horticulture/dairy, tea/dairy, sheep/dairy, wheat/dairy and Nairobi are identified in the eight districts. Three population density classes are identified as well: less than 200 inhabitants per Km^2, between 200 and 500, and more than 500 (C.B.S 1994). As a result, twelve stratification groups are then considered (not eighteen since some combinations do not exist such as tea/dairy in less than 200 density areas) and some combinations were grouped to avoid obtaining very small groups.

It was calculated that eighty-nine households had to be surveyed per stratification group, in order to estimate a difference between two means at 20% with a confidence level of 95% and hypothesising a coefficient of variation of number of cows of 68% (based on results from Kiambu data). The calculation of sample size in each stratification group is:

$$n = 2\left[\frac{z.c}{d}\right]^2$$

where z = 1.96 for 95% confidence interval, c is coefficient of variation and d is level of difference (Poate and Daplyn 1993).

The size of the sample in Nairobi is arbitrary increased to 280 in order to increase the probability to include agricultural households.

The sample size in each sublocation is calculated as a proportion of the number of households in the corresponding stratification group (self-weighting sampling within strata). Moreover, if the calculated sample size was less than 10, it was arbitrary fixed at 10 in order to get enough households per sublocation to collect accurate data on prices and milk marketing infrastructures. The resulting calculated sample size is 1401. However, data of 1375 households were finally collected because of an initial overestimation of the population in one of the surveyed division.

Weights are calculated in a similar way to those for the Kiambu survey. The first stage of the sampling process requires calculating weights as the inverse of the probability to select a sublocation in the corresponding district. The second stage, i.e. selection of the number of

households to be surveyed in the sublocation is a self- weighting process since the sample size in each sublocation is proportional to the number of households in the corresponding stratum.

The following table summarises the sampling design and presents the sampling levels used in the empirical analyses of the next chapters:

Table 4: Sampling designs of the two surveys used in the analyses

Sampling units	Kiambu survey	Other districts survey
strata	1	12 (farming system* human population density class)
cluster (sublocation)	24	82
weights	1/ [probability selecting a sublocation in the AEZ]	1/ [probability selecting a sublocation in the district]

5.3. The survey implementation

Survey maps for each sublocation were created from ILRI geographical information systems (GIS) databases, using ArcInfo software. The survey enumerators, who had previously been trained in the use of the survey instrument, visited their assigned sublocations and marked on the map the main landmarks (any permanent feature like a trading centre, a school or a church). Two (or three) pairs of landmarks were then selected at random for each sublocation and line transects were drawn joining each pair. Sampling was thereafter done following as closely as possible the marked transects. Every 5th household on the left and on the right was interviewed alternately, regardless of whether they were agricultural or kept dairy animals. In this way, a random sample of all sublocation households was obtained (Staal *et al.* 1998 for the "Kiambu survey" and 1999 for the "other districts survey").

The questionnaires were completed through interviews with the household head or in his/her absence, the most senior member available or the household member responsible for the farm. Enumerators were asked to make appointments if this person was not available. Enumerators were selected among the front-line and supervisory extension staff of the Ministry of Agriculture in each district. A supervisor checked each completed questionnaire in order to get as accurate information as possible. The data from the questionnaires were entered into EpiInfo data management software and checked for data entry errors.

The questionnaire are divided into sections covering: household composition, labour availability and use; farm activities and facilities; livestock inventory; cattle feeding, dairying with emphasis on milk production and milk marketing; livestock management and health services; household income and sources; and co-operative membership and milk consumption. Two main factors are suspected to both play an important role in adoption and to vary in time; owned land size and household composition. For the other districts survey, values for these two variables were then collected at each point of time using recall questions. Key events, the years of household formation and the year of dairy cattle adoption were recorded as well.

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

Each household was then assigned to the nearest node or intersection in the network using geographic information systems (GIS) software (workstation ARC/INFO, ESRI 1998) by the ILRI GIS department. Distances were calculated by road types, i.e. total distance was divided into three sections corresponding to the three road types. Differentiating the total distance by road type gives a more accurate measure of accessibility since travel times and costs are expected to be higher for secondary roads compared to tarmac roads. Availability of these GIS-derived distances contrasts with previous studies that were restricted in the analysis by using locational dummy variables or reported distances (thus not allowing distinction by road types).

Moreover, the information on each household's geographic position enables to link the survey data with other datasets. In the analyses that follow, two other sources of information have been used. The first source is the ILRI- Nairobi GIS database from which data on tick distribution and rainfall data (using data on meteorological stations) are extracted. The second source is the database "Almanac Characterization Tool" of Texas A&M University (Corbett 1999) that provides data on climatic conditions, and especially an indicator for the area suitability for crop and livestock production (PPE -annual precipitation over overall potential evapo-transpiration ratio) and minimum temperature.

6. Conclusions of chapter 1

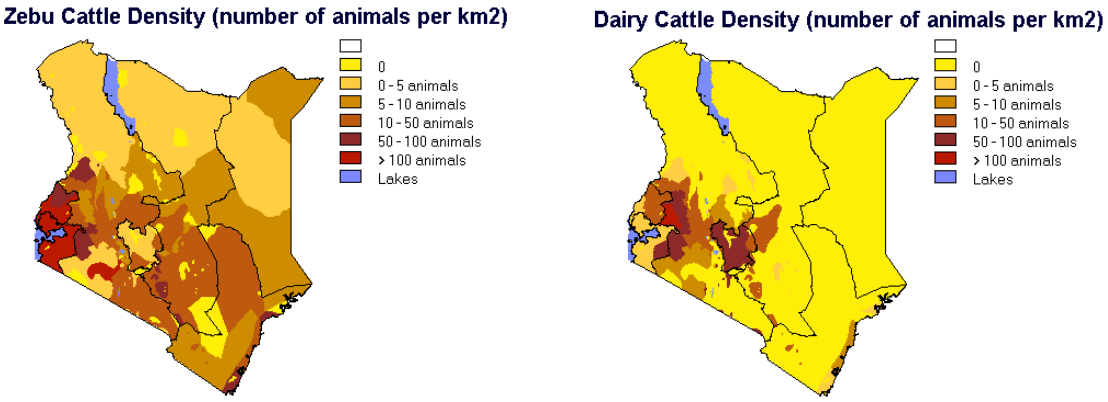
Dairying offer good opportunities for smallholders in terms of income generation, income stability and employment opportunities. Moreover, grade cattle are available in the surveyed area and previous experience with the European settlers has shown that these animals are suitable to the climatic conditions. However, the entry cost into dairying is high; production risks are important also since grade cows are sensitive to tick-borne diseases contrary to local cows; thirdly, milk marketing is characterised by high transaction costs that may prevent farmers from entering into the activity.

The liberalisation of the dairy industry opened a new era for the dairy sector. With the progressive withdrawal of government livestock services and the end of KCC monopoly on the urban milk sales, 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, especially in the areas where dairying is less market- oriented (Omore *et al.*). The analyses that follows give some insights about the consequences of the liberalisation of the dairy sector on the rate of adoption of the grade cattle technology.

The next three chapters seek to better understand the patterns of adoption of the grade cattle technology. Because the entry cost into dairying is high, some farmers used a way to "avoid" purchasing their first grade cow, either by getting it at no cash cost or by upgrading progressively local animals. However, data show that few farmers have chosen this option. Chapter 2 investigates this specific topic.

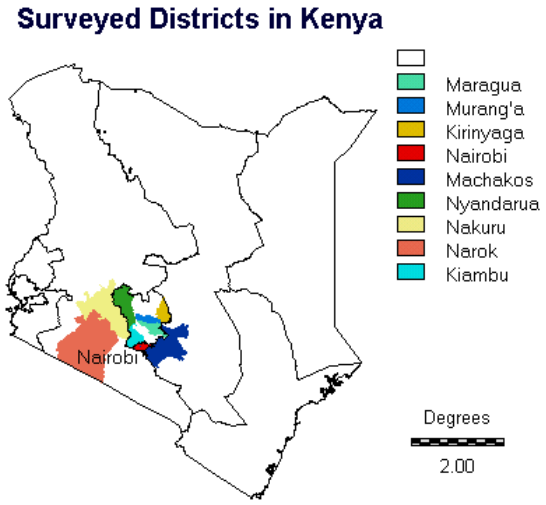
Annexes

Annex 1: Maps of distributions of Zebu cattle and grade cattle



Sources: ILRI- Nairobi GIS databases.

Annex 2: Map of the surveyed area



Sources: ILRI- Nairobi GIS databases.

Chapter 2

Entering into dairying: Is there another route besides purchasing?

1. Introduction

One of the main constraints to the adoption of the grade cattle technology identified in chapter 1 is the entry cost i.e. the cost of a grade cow. While grade cows reach higher milk production levels than local cows, farmers may find it financially difficult to meet the cost of the first grade cow. Alternative ways to get a grade cow can then be explored by the farmer. Two main other routes besides purchasing are used: getting a cow at no cash cost and upgrading progressively local cows.

This chapter aims at understanding the choice of the different strategies, focusing on upgrading as an alternative route to purchasing. While getting a grade cow at no cash cost is an ideal alternative, gift experiences are unique to the household who benefited from them and no policy recommendations can be deducted. Section 2 explores this route and gives some examples. Section 3 deals with the strategy of upgrading. The analysis is constrained by the small number of farmers who actually took this route. Nevertheless the empirical analysis supports the hypothesis derived from the modelling. Section 4 concludes on the farmer's opportunities to enter into dairying without bearing the cost of a grade cow.

2. Entering dairying at no cash cost

Getting a grade cow at no cash cost is the route followed by almost 6% (52 farmers) of the dairy farmers surveyed, ranking this strategy second after purchasing, but before upgrading. The constraints associated with purchasing constitute the topic of chapters 3 and 4 while the upgrading strategy is analysed in section 3 of this chapter.

Entering dairying at no cash cost means getting a grade cow as a gift from the family, relatives, project or other groups. Gifts from the family usually take place when inheriting the land: cows may be inherited at the same time and no cash transfer is asked. The other way is to belong to a solidarity network, e.g. a church group. The example of Zedi who got her first cow from a church group is described in box 1.

Box 1: getting the first grade cow at no cash cost: the example of Zedi in Nakuru district
Zedi's husband is the pastor of the church of the area. Their farm is actually situated next to the church. When they settled in Nakuru eight years ago, Zedi, who is in charge of the farm, was lucky: she received a dairy cow from relatives and people from the church. In 1999, the cow was sold and Zedi decided to buy a younger cow that produces more. Savings from milk sales financed the difference between the price at which she sold the first cow and the cost of the second cow. This is how Zedi became a dairy farmer.

This entry into dairying may not be completely free because the family/group may expect something in exchange or the project requires some conditions to be met. The cost is difficult to assess but can nevertheless be considered as negligible when compared with the market value of the animal.

The statistical analysis shows that farmers who entered dairying at no cash cost do not seem to share specific characteristics. They do not live in a specific area, nor do they belong to a specific ethnic group. Table 1 presents some statistical results, dividing the sample into farmers who got their first grade cow at no cash cost and the other dairy farmers.

Table 1: Variables means, by routes to enter dairy farming

Variables	At no cash cost	Other routes	Statistical difference
Number of observations	52	853	
Sex of the household head (1 if male)	0.75	0.76	-
Age of the household head at establishment	30.43	30.65	-
Years of formal education of the household head	9.33	8.31	10%
1 if the household is Kikuyu, 0 otherwise	0.87	0.91	-
Year when established the farm	1983	1977	1%
Land size at establishment (acre)	6.59	6.94	-
Distance to the nearest urban centre, all-weather road (km)	28.16	33.90	5%
Distance to the nearest urban centre, dry-weather road (km)	2.51	2.77	-
1 if the area is infected with ticks, 0 otherwise	0.87	0.81	-

The analysis of table 1 reveals that farmers who benefited from solidarity network have few common (observable) characteristics. The education level is different between the two groups: farmers who benefited from a "gift" are more educated. They established their farm after the other farmers and are relatively closer to the urban centres.

It can be hypothesised that "lucky" beneficiaries are more likely to be households in need. Land size may be an indicator of the possible financial weakness of the household, as farmers with

limited land size are more susceptible to negative shocks. However, the land size does not differ significantly between the two groups.

Experiences of farmers who started dairy farming by getting their first grade cow at no cash cost are farmer-specific. Policy recommendations to promote adoption of dairying through this route cannot be deducted. The next section aims at determining whether the same conclusion applies to the third most followed route, namely the upgrading strategy.

3. Entering dairying through upgrading

3.1. Definition of upgrading

Upgrading is the process by which a farmer decides to increase the percentage of dairy genes of the herd. Cows at the beginning of the process are local breed animals; through breeding using artificial insemination or dairy bulls, future cows are progressively upgraded as the percentage of dairy (or exotic) genes increases. The process is long and risky since the upgraded animals may die before reaching the final state of a pure grade animal.

Upgrading was the strategy followed by the Kenyan government at Independence to turn the herds of local cattle into high-producing animals. Box 2 describes how upgrading was used to increase the number of grade animals in Kenya after Independence.

Box 2: How upgrading was promoted to increase the number of grade animals after Independence

"The population of Zebu cattle declines steadily as the population of grade cattle increases. By means of A.I. [artificial insemination], the country has been able to turn many Zebu heifers into future grade cattle. This project is very much welcomed by the farmers because many of them have started experiencing more milk yields from the upgraded cows and also reducing the period on calving interval". Ministry of Agriculture, Central Province annual report 1974, p.37.

The government extended the artificial inseminations services in the smallholder areas; where it was not possible, bull centres were established.

Upgrading enables to reduce the lumpiness of the entry cost, but few farmers actually report to have upgraded their local animals (less than 4% of the farmers with grade animals). On the contrary, the main route toward dairying is the purchase of a grade cow. This section aims at identifying the determinants of choice between the different strategies and at understanding why the survey data present only few examples of upgrading strategies.

3.2. The theoretical setting

The choice between upgrading and purchasing is analysed using three levels of analysis. The first level deals with the characteristics of the area; the second level introduces farmer characteristics; the third level takes into account the date at which the surveys were conducted.

3.2.1. Area characteristics

Upgrading is an alternative route toward dairying in areas where local cattle are historically present. It is worth noting that not all the area covered by the surveys actually meet this condition. Two areas, namely Nakuru and Nyandarua are mainly settlement areas, where farmers settled there after Independence. For those households, upgrading is not an alternative since local cows were not widely available in these districts.

Another area characteristic is the incidence of tick-borne diseases. Grade cows are more sensitive than local cows to tick-borne disease; on the other hand, crossbred cows (resulting from the process of upgrading) are expected to be more resistant. Farmers living in areas infected by tick-borne diseases may thus prefer upgrading, *ceteris paribus*.

3.2.2. Farmer characteristics

At the farmer level, the choice between upgrading and purchase can be seen as the result of a trade-off between time and cost. Purchasing enables the farmer to get a grade cow at no delay but costs him p_c the year of the purchase. On the contrary, upgrading costs less, p_u with $p_u < p_c$, but the process takes several years before the upgraded animals reach the milk potential of a grade cow.

The farmer thus compares the benefits derived from the two strategies and chooses the strategy generating the highest benefits. The discounted benefits of purchasing a grade cow at time t_0 are designed by B_{t0}^{p} and are equal to:

$$B_{t0}^{p} = \sum_{t=1}^{n} \frac{(p_{m,t} - TC_t).q_t^p}{(1+\rho)^t} - p_c$$

where $p_{m,t}$ is the milk price at t, TC_t represent the transaction costs on the milk market, q_t^p is the quantity of milk sold at t, ρ is the discounted time factor and p_c is the cost of a grade cow purchased at $t=t_0$. The expected lifetime of the cow is n.

On the other hand, upgrading generates the benefits B_t^u that are equal to:

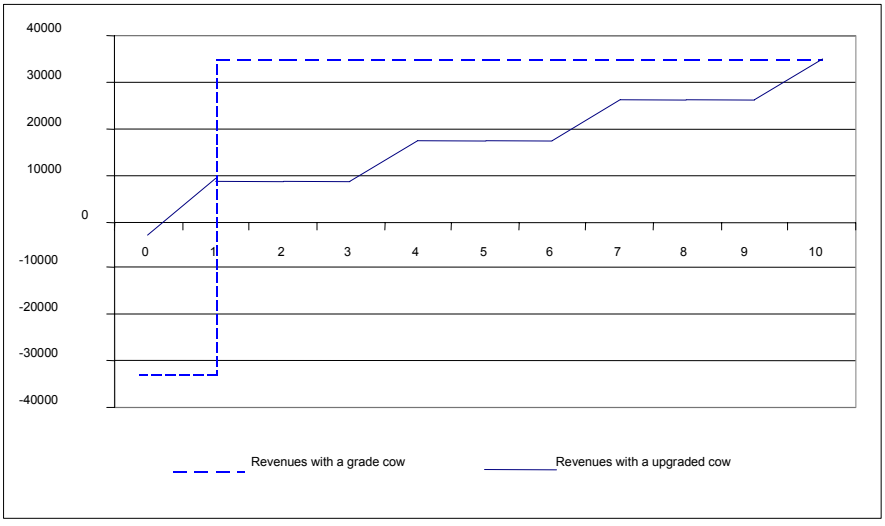
$$B_t^u = \sum_{t=1}^{n} \frac{(p_{m,t} - TC_t).q_t^u}{(1+\rho)^t} - \sum_{t=1}^{m} \frac{p_u}{(1+\rho)^t}$$

where m is the number of times (years) the cow is inseminated. The quantity of milk sold at time t is q_t^u. All the other variables remain the same.

By definition, $m<n$ and $q_t^u < q_t^p$ since a local and a crossbred cow have a lower milk potential than a pure grade cow, *ceteris paribus*.

From the comparison of the two discounted benefits, it can be hypothesised that purchase is preferred to upgrading by farmers benefiting from high milk prices, i.e. for which transaction costs on the milk market are low. In fact, the term $(p_{m,t} - TC_t)$ that multiplies the quantity sold is higher; farmers are incited to purchase rather than upgrading in order to reap the benefits of selling milk at a high price. Transaction costs on the milk market are assessed by the distance to urban centres. This is clarified in the following graph that plots the revenues (in Ksh: US$1=approximately 60 Ksh at the time of the survey) from purchasing a grade cow and the revenues obtained by progressively upgrading a local breed cow (y-axis) over the years (x-axis). The hypotheses are detailed in annex 1.

Graph 1: Comparing the revenues from purchasing a grade cow and upgrading progressively a local breed cow



Box 3 presents the example of Consolata whose current grade cow is the result of an upgrading process.

Box 3: Getting a grade cow through upgrading: the example of Consolata in Murang'a district
The farmer is an old woman, now a widow. Her husband and her established their farm in 1940; they had a local cow. Then, by progressive upgrading, the farmer managed to turn the local cow into a grade cow: the upgrading process ended approximately in 1965. The process was rendered difficult by the fact that artificial insemination services were not widespread and bulls were mainly from local breeds.
The process of upgrading took approximately 25 years on this farm. But the farmer had no cash to purchase a grade cow and preferred the slow but cheaper process of upgrading. The farm is situated far from the main road and milk marketing is limited. The household had thus no incentives to increase the milk production for sale.

3.2.3. Date of the survey

The data used in the empirical analysis have been collected in 1996 for Kiambu and 1998 for the other districts. It means that the majority of the surveyed farmers do not belong to the first generation of farmers after Independence (1963). The process of upgrading began at Independence when the Kenyan government promoted smallholder dairying. It is essentially the first generation of farmers after Independence who had to decide between upgrading and purchasing. Their successors found grade cows on farm and purchased them from their parents. The example of Kabingo in Murang'a district illustrates the process: his story is summarised in box 4.

Because of this historical background, it is not unexpected to have surveyed only few cases of upgrading as a route toward dairying.

Box 4: Purchasing upgraded cows from his father: the example of Kabingo in Murang'a district
Kabingo is a young farmer who established his farm less than 10 years ago. He has four high-grade animals, one cow, one heifer and two calves. He bought his animals from his father who is now retired. His father did not buy them; he upgraded them progressively since he had local animals before. Kabingo used to work off-farm; this is how he managed to pay his father when he established his own farm.

3.3. The empirical analysis

Data show that less than 4% of the surveyed dairy farmers chose upgrading to get a first grade cow, corresponding to 34 observations. The empirical analysis is thus constrained by the small number of observations. The following results emerge from the analysis.

3.3.1. Testing the hypothesis using statistical relationships

Three levels of analysis were considered in the theoretical framework: area, farmer and date of the survey.

Table 2 shows that the farmers who used the upgrading strategy to enter into dairy farming are not uniformly distributed across districts:

Table 2: Farmers distribution, by districts

Districts	Upgrading		Other routes		Total
	number	percentage	number	percentage	
Settlement districts					
Nakuru	4	1.9	207	98.1	211
Nyandarua	0	0.0	93	100	93
Other districts					
Kiambu	2	0.8	245	99.2	247
Kirinyaga	4	5.4	70	94.6	74
Nairobi	1	7.7	12	92.3	13
Narok	0	0.0	8	100.0	8
Machakos	2	9.1	20	90.9	22
Maragua	1	1.6	60	98.4	61
Murang'a	20	13.1	133	86.9	153
Total	34	3.9	848	96.1	882

The table indicates the number of farmers per district who chose upgrading to start dairying (second and third column) and the other routes (fourth and fifth column).

Upgrading is more frequent in districts where there were originally local animals: these districts are Murang'a (13.1 % of the dairy farmers in the district used upgrading), Machakos (9.1 %) and Kirinyaga (5.4%). Nairobi district exhibits a relatively high percentage as well (7.7%). Moreover, settlement areas like Nyandarua and Nakuru have very few (or no) farmers who choose that route. The result concerning Narok district is unexpected: none of the Narok farmers upgraded their animals, yet Narok is a pastoral area (Maasai land) where local animals are widely available. However, caution must be exercised when interpreting these results because of the limited number of observations in each district.

The other area characteristic that may have an influence on the decision is the distribution of tick-borne diseases. Using the GIS indicator for the presence of ticks described in chapter 1, households are classified whether their farm lies in a tick-infected area or not. Statistical results show that 4.04% of the households in tick-infected areas chose upgrading, versus 2.47% of the households whose farms are in areas not infected by ticks. However, the difference is not statistically different.

At the farmer level, it is hypothesised that transaction costs influence the decision between the routes since the existence of high transaction costs makes the purchase of a grade cow less profitable. Transaction costs are assessed by distances to urban centres, distinguishing two road types (all-weather roads and dry-weather roads). The statistical analysis shows that farmers who upgraded are further away from the nearest urban centre on all-weather roads but not on dry-weather roads. The difference is statistically significant at 10%. Table 3 presents the results.

Table 3: Mean of some variables, by route

Variables	Upgrading	Other routes	Statistical difference
1 if the area is infected with ticks, 0 otherwise	0.88	0.81	-
Distance to the nearest urban centre, all-weather road (km)	38.6	33.4	10%
Distance to the nearest urban centre, dry-weather road (km)	3.1	2.7	-
Years of establishment	1973	1977	10%
Land size at establishment (acre)	6.43	7.03	-

Farmers who chose the upgrading strategy are, on average, 5 km further form the nearest urban centre, compared to the other dairy farmers. Distance from the farm to demand centres thus seems to affect the choice between routes toward dairying.

Finally, the third level of analysis deals with the date of the surveys. It is hypothesised that the majority of the surveyed farmers are not the immediate post-Independence farmers, for which the choice between upgrading and purchasing was relevant. The analysis of the data shows that farmers who reported upgrading have established their farm in earlier years, in comparison with the other dairy farmers (see table 3). Moreover, 7.8% of the dairy farmers who established between 1954 (Swynnerton Plan that allows Kenyans to keep grade cattle) and 1970 (post-Independence period) chose the upgrading strategy, *versus* 2.8% for farmers who established their farm after 1970. Upgrading was thus a preferred strategy in the earlier days of smallholder dairying.

The statistical analysis thus does not reject some of the hypotheses enounced in the theoretical framework. However, it does not take into account the relationships between variables. An econometric analysis is thus conducted in the following section.

3.3.2. An econometric analysis of the choice between the routes toward dairying

Because of the limited number of farmers who chose upgrading, the econometric analysis is conducted with resampling. Farmers who upgraded are sampled at 100% while other dairy farmers are sampled randomly at 10%. The resulting sample contains 119 observations, of which 34 chose upgrading (28.6%).

With random (or equiproportionate) sampling, the coefficients of a logit estimation are "all unaltered" (Maddala, p. 91), except for the constant term which needs to be readjusted. The effect of resampling on the probit model is more complex; a logit model is thus estimated.

The variable U_i indicates whether the farmer chose upgrading as a strategy to enter dairying (U_i=1) or not (U_i=0). A set of factors X_i is assumed to explain this decision and the logit model is used to estimate the model. In this model, the probability of choosing upgrading is written as:

$$(1)\ \text{Prob}(U_i) = \frac{\exp(\beta'.X_i)}{1+\exp(\beta'.X_i)} = F(\beta'.X_i)$$

where β is the vector of unknown coefficients to be estimated by maximising the log-likelihood. The likelihood function is written as follows:

$$(2)\ L = \prod_{U_i=1} F(\beta'.X_i).\prod_{U_i=0}(1-F(\beta'.X_i))$$

And the log- likelihood to be maximised is:

$$(3)\ \ln L = \sum_{U_i=1} \ln F(\beta'.X_i) + \sum_{U_i=0} \ln(1-F(\beta'.X_i))$$

The theoretical framework developed in section 3.2 is used to identify the key determinants X_i of choice between the strategies towards dairying. The included variables are the area characteristics (if the district was a settlement area or not; presence of ticks responsible for cattle tick-borne diseases); some farmer's characteristics (distance to the nearest urban centre, by road type) and the date when the farm was established. Two other farmer's characteristics are included: the age of the household head at establishment and the education level. Younger households have a longer time-horizon, thus are expected to prefer upgrading. Education is hypothesised to have a negative role in the decision to upgrade as more educated households are expected to adopt faster (thus purchasing rather than upgrading).

Because of the strong in– build collinearity between the two area characteristics (settlement areas are less infected with ticks), the two variables cannot be introduced simultaneously. Since

there is no reason *a priori* to prefer one of the variables, two specifications are estimated. Table 4 presents the results of the estimations using a logit model: the first specification includes the dummy variable indicating whether the district was a settlement area or not; the second includes the dummy variable whether the farm is in a tick- infected area. The reported coefficients for the constant are adjusted to account for the resampling procedure. More precisely, the constant term is increased by the term (log p_1 – log p_2) where p_1 designs the sampling rate for the sub-population of farmers who chose upgrading and p_2 the sampling rate for the other sub-population (Maddala, p. 91). In the studied case: log p_1 – log p_2 = log(0.1) –log (1)= -2.303.

Table 4: results of the Logit specification for the decision to upgrade

1 if the farmer used upgrading as a route toward dairying, 0 otherwise				
Variables	**Coefficients**	**P>|z|**	**Coefficients**	**P>|z|**
Area characteristics				
- 1 if settlement area	-1.311	0.068	not included	
- 1 if the farm is in a tick- infected area	not included		0.452	0.541
Household's characteristics				
- Age of the head (at establishment)	0.012	0.564	0.006	0.780
- Education level of the head (years)	-0.144	0.031	-0.124	0.061
- Distance to the nearest urban centre, all-weather roads	0.024	0.143	0.030	0.068
- Distance to the nearest urban centre, dry-weather roads	0.095	0.209	0.108	0.172
Year of establishment	-0.016	0.425	-0.022	0.274
Constant (adjusted for the resampling procedure)	-2.111	0.907	-2.503	0.913
Number of observations	112		112	
Percentage of correctly predicted observations, upgrade=1	75.00		66.67	
Percentage of correctly predicted observations, upgrade=0	77.00		73.58	
Overall percentage of correctly predicted observations	76.79		73.21	

Results are satisfactory in terms of percentages of correctly predicted observations: 76.8% for the specification using the settlement variable and 73.2% for the specification with the tick distribution variable. However, few variables seem to have a significant effect on the decision to upgrade *versus* the other routes. The variables whose coefficients are statistically significant at conventional levels are consistent with the predictions of the theoretical model.

When analysing the results of the specification with the settlement variable, two variables have a significant effect (below 10%): the education level of the household head and the settlement variable. More educated farmers are less likely to chose upgrading, *ceteris paribus*. The same can be concluded for farmers in settlement areas. Calculating marginal effects enables to precise the

predicted effects for these two variables. In a logit model, the marginal effect for a continuous variable is calculated as follows:

$$(4)\ \frac{\partial E[U_i|X_i]}{\partial X_i} = F(\beta'.X_i).[1 - F(\beta'.X_i)].\beta$$

where $F(\beta'.X_i)$ is defined in equation (1).

For binary (dummy) variables, equation (4) does not apply. The marginal effect for a binary variable *b* is thus assessed by equation (5):

$$(5)\ \text{effect} = \text{Prob}(U_i = 1|\overline{X_i}, b = 1) - \text{Prob}(U_i = 1|\overline{X_i}, b = 0)$$

where $\overline{X_i}$ denotes the means of all the other variables in the model.

Using equation (4) for the level of education, four more years of formal education (e.g. from primary to secondary education level) decrease the likelihood of choosing upgrading to enter into dairying by 10.3%. And farmers situated in settlement areas are less likely to use the upgrading strategy by 23.3% (using equation (5)).

Turning to the second specification, two variables are significant and with the expected sign: the level of education and the distance to the nearest urban centre. Farmers educated at the secondary level are less likely to use the upgrading strategy by 9.1%, compared to farmers with a primary level of education: this result is consistent with the result obtained in the first specification. And a farmer situated ten kilometres further from a town is more likely to choose upgrading *versus* the other routes by 5.5%. Note that the variable indicating whether the farm lies in a tick- infected area is not significant.

3.4. Analysis of the results and conclusions

The analysis is constrained by the limited number of households who chose upgrading as the route toward dairying. However, the empirical analysis presents some interesting results. The statistical analysis shows that upgrading is a strategy mainly followed by the first generation of farmers after Independence. Very few farmers opted for it after mid 1970s. One explanation for this evolution may be related to the development of the marketing infrastructures, making the direct entry into dairying through purchasing financially profitable.

The econometric analysis has identified three main determinants for the choice of the upgrading route: the fact that farmers live in settlement areas (where no local animals are widely available), the education level of the household heads (more educated farmers are assumed to adopt "faster", avoiding the long process of upgrading) and distance to urban centres (farmers situated far from urban centres are induced to upgrade since the incentive to reach higher levels of milk production by purchasing a grade cow is lower).

4 Conclusions of chapter 2

This chapter aims at analysing two specific ways to start dairy farming, namely getting a grade cow at no cash cost and upgrading local animals. Gift experiences are shown to be farmer-specific and no policy recommendations can be derived. As for the upgrading strategy, the data show that this strategy was mainly followed by the first generation of farmers after Independence. Farmers facing high transaction costs on the milk market are less induced to enter into dairying at a high cost and thus prefer the slow but cheaper process of upgrading their local animals. Finally, upgrading is less likely for farmers in settlement areas where the availability of local animals is limited.

These strategies to start dairy farming thus concern but a few farmers. The main route toward dairying is through the purchase of a grade cow: the analysis of the adoption decision by farmers who purchased their first grade animal is the topic of the following two chapters.

Annexe

Revenues from purchasing a grade cow and from upgrading progressively a local breed cow

The hypotheses of graph 1 are as follows. The sale milk price is set at 12 Kenyan shillings (or approximately US$0.2) per litre (the same for the two routes). The purchase price of a grade cow is set at 35,000 Ksh and the cost of a local cow at 3,500 Ksh. The price of a grade cow reflects the total value of milk that a cow is expected to produce in a year (Omore *et al.* 1999).

The grade cow is assumed to produce 8 litres per day throughout the year. This is an approximation that averages the high production levels at calving and the low levels at the end of the lactation. The reported levels of production are only those of the cow bought in year 0 and do not include the production of the following cows ("descendants" of the first cow).

The local breed cow (A) is assumed to produce two litres at the beginning of the upgrading process (year 1 to year 3). In year 0, cow A is inseminated and calves an upgraded calf B. Calf B is supposed to be a female and is mature at year 4 when it starts producing 4 litres per day. In year 4, cow B is inseminated and calves an upgraded calf C. Again calf C is supposed to be a female and is mature at year 7 when it starts producing 6 litres per day. The process continues until year 10. As in the case of the grade cow, the reported milk production levels only include the production of one cow; in this case, it is the cow that is "the most upgraded" (first cow A, then cow B…).

The hypotheses are very simplified and do not take into account (1) the variation in milk production during and over the years and (2) the observed long calving intervals. These simplifications are set in order to concentrate on the studied case: purchasing *versus* upgrading. The following table gives the details of the calculations plotted on graph 1:

years	Revenues from purchasing a grade cow	Details of the calculations of purchasing	Revenues from upgrading a local breed cow	Details of the calculations of upgrading
0	-35000	-35000	-3500	-3500
1	35040	12*8*365	8760	12*2*365
2	35040	12*8*365	8760	12*2*365
3	35040	12*8*365	8760	12*2*365
4	35040	12*8*365	17520	12*4*365
5	35040	12*8*365	17520	12*4*365
6	35040	12*8*365	17520	12*4*365
7	35040	12*8*365	26280	12*6*365
8	35040	12*8*365	26280	12*6*365
9	35040	12*8*365	26280	12*6*365
10	35040	12*8*365	35040	12*8*365

Chapter 3

Does access to credit facilitate the route toward dairying?

1. Introduction

The analysis in chapter 1 identified the entry cost as the major constraint to the smallholders' adoption of the grade cattle technology. For farmers who could not benefit from a "network" to get an animal at no cash cost, credit facilities can be used to finance the cost of the first grade cow. However, credit facilities are limited in Kenya. Government reports described credit for dairy farming as "inadequate" (Government of Kenya 1997) and previous works have analysed the importance of credit in dairy farming. In a study on the credit constraints for smallholder dairy production in the East Africa Highlands, Freeman *et al.* (1998) show that credit targeted on the credit-constrained farmers would have a higher impact on milk output (compared to credit non-constrained farmers) through the purchase of crossbred cows. Concerning the effect of lack of credit facilities on the adoption of grade cattle technology, no formal test has yet been conducted. The objective of this chapter is to test whether access to credit facilitates the adoption of grade cattle technology in the studied area.

The second section presents some background information on credit facilities for dairying in Kenya. The focus of section 3 is to develop a theoretical model of the adoption decision in order to identify the factors that have to be introduced in the empirical setting, as well as their expected effects on the adoption decision. Section 4 addresses the empirical issue of access to credit and presents the econometric estimation. In section 5, the empirical analysis of the decision to adopt grade cattle technology is conducted, using the results of the previous sections. Section 6 concludes about the major incentives and constraints to smallholders' adoption: it cannot be rejected that credit facilities ease the smallholders' entry into grade cattle rearing. Moreover, the availability of livestock services (artificial insemination, veterinary and extension services) increases farmers' incentives to adopt. However, results suggest that farmers face more difficult conditions since the 1992 liberalisation of the dairy sub- sector: in fact, the smallholders' entry into dairying is less likely compared to the previous periods.

2. Access to credit for dairying in Kenya

There are different channels through which a farmer can get a loan to start dairying. Historically, credit for dairy activities started before the Kenyan Independence, with the Swynnerton plan in 1954 implemented by the British colonial government (Conelly 1998). The objective was to promote Kenyan smallholders' farming as described in chapter 1. After Independence, farmers could get a loan through the resettlement schemes, which not only assisted households to buy land but also to acquire dairy animals. Prices of grade cattle were highly subsidised and in the previously "White Highlands", many farmers can still recall this period when they purchased a grade cow with the help of the government. Njuguna's story described in box 1 is a common example.

Box 1: Benefiting from the Resettlement Schemes to start dairying: the example of Njuguna in Nyandarua district

Njuguna is now above 70. At Independence, he applied to the resettlement scheme in Nyandarua district in order to get a piece of land for his family. Plots were allocated by ballot, whereby the future farmer pays a "raffle ticket" at a very low price compared to the actual value of the land. Njuguna also applied to buy two grade cows, originating from a nearby white settler farm. The price of the two cows was highly subsidised by the government. This is how he entered into dairying.

Since then, the institutions providing credit to smallholders have become more diversified. Three types of loans can be distinguished, loans directly provided to farmers, loans channelled through co-operatives and other types of loans. They are detailed in the following sections.

2.1. Institutions providing loans directly to farmers

There are two main institutions providing loans directly to farmers: the Agricultural Finance Corporation (AFC) and commercial banks.

The AFC was created in 1963 and merged in 1969 with the former Land and Agricultural Bank of Kenya (which started before Independence) to form the actual AFC. The main objective of the institution is to provide credit to farmers. It is not a commercial bank and no deposit is asked from farmers. As a government-owned organisation, the Agricultural Finance Corporation proposes loans to smallholders at a fixed interest rate that is lower than the prevailing rate charged by commercial banks. Some farmers apply directly to commercial banks, but it is limited to well-off farmers who can afford the high interest rates charged. Conditions asked by AFC are less restrictive and the interest rate is lower, but many farmers still find the requirements difficult to meet.

AFC gets funding from donors (World Bank and Government of Kenya), as loans (at 4%, with the guarantee of the Kenyan government). Currently there is no more funding from the Kenyan Government and the major source of funding is the farmers' repayments. Note that some projects are targeted for specific activities, i.e. the funds have to be lent to specific agricultural activities (e.g. dairying). AFC' s clients are mainly farmers; the institution also lends to co-operatives (but co-operatives fund their activities mainly with the Co-operative Bank).

AFC requirements are not accessible to all smallholders, making AFC loans not very common. In fact, AFC follows the standard banking rules, in particular in relation to the collateral. Collateral may take the form of land title deeds, which may be difficult to produce for some households, either because the land has not yet been legally registered or more often nowadays, the land has not yet been sub-divided. In the latter case, the title deeds do not show the name of the willing entrepreneur, preventing her from getting a loan from AFC. More details on AFC requirements are presented in box 2.

Box 2: AFC requirements to attribute a loan

AFC follows the rule of the 5 "C":

- the Character of the borrower is assessed through interviews (main activity, responsibilities in the local community...);
- the Capacities of repayment: the project budget should indicate that the cash flows generated by the new activity are sufficient to pay back the loan;
- the financial Conditions of the borrower, i.e. her indebtedness;
- the Collateral: land, title deeds, car log-book, shares (from reputable companies), fixed deposits certificates. AFC loans do not exceed 75% of the value of collateral;
- the Contribution of the applicant has to amount to at least 25% of the cost of the project.

In order to monitor the farmers who take a loan, AFC has a network of loan officers who are in charge of providing advises, helping managing the project and if necessary, collecting arrears. When a borrower does not meet its obligations, AFC has thus some insights whether it is because the farmer is unable or unwilling to repay. In the first case, AFC's official policy is to extend the repayment period; in the later case, AFC sells the security.

Source: personal interviews with AFC (AFC does not publish reports)

Another limitation to the role of AFC is the diminishing funding, preventing the institution from meeting the actual demand for credit. This can be assessed in annex 1, which presents the amount of loans disbursed by AFC for dairying from 1972 to 1994.

Despite these limitations, AFC plays an important role in the agricultural sector in Kenya. The example of Ruto, a farmer in Nakuru district shows how a loan from AFC enabled him to buy a grade cow (box 3).

Box 3: Getting a loan from AFC to start dairying: the example of Ruto in Nakuru district
Ruto got a loan from AFC in 1990 to start dairying. There were many conditions to meet before getting the loan: 1. the land title deed was handed out to AFC through the land register; 2. the farmer and AFC agreed that a portion of land will be sold to recover the loan in case of failure to pay back the loan; and 3. the extension officer checked whether the farm was appropriate for dairying (land size for grazing and fodder, water availability and dairy equipment). The farmer was helped to fill the forms by the extension officers of the Ministry of Agriculture, so that the farmer found the application easy. The repayment period was 5 years, and he knew that if he failed to repay, a portion of land was to be sold to recapture the loan.

2.2. Institutions channelling loans to farmers

The second channel to get a loan is to apply to a co-operative credit scheme. It is worth noticing that since Independence, the co-operative movement has been encouraged by the Kenyan government in order to promote agricultural development. Dairy co-operatives were among the biggest co-operatives in Kenya, both in terms of membership and cash flows (Ouma 1980). Since the liberalisation of the dairy sector in 1992, dairy co-operatives are less involved in the development of the sector and their importance is diminishing.

Some co-operatives channel loans to their members. The disbursing agent is either Co-operative Bank or the union to which the co-operatives belongs. The situation varies between co-operatives in terms of types of programmes and amount lent and data on the amount of loans and the number of farmers involved in those programmes are not available. As an example, the co-operatives loan programmes in Kiambu district are presented in box 4. In addition, Thyaka's recall of how he purchased his first grade cow through a loan from his co-operative is presented in box 5.

Box 4: Co-operatives' loan programmes in Kiambu district
In Kiambu, two programs were recently operational, the Co-operative Development Fund (C.D.F.) and the Co-operative Production Credit Schemes (C.P.C.S.).
The C.D.F. program operated in 1995. In Kiambu district, Co-operative Bank disbursed 4.7 Millions Ksh to two dairy co-operative societies: Kikuyu Dairy Farmer Co-operative (1.2 Millions, for 32 members) and Ndumberi Dairy Farmer Co-operative (3.5 Millions, unknown number of members concerned). The loans were targeted to purchase dairy cows.
The disbursing agent of the C.P.C.S. program is the Kiambu dairy and pyrethrum union. Since the creation of the union, the scheme has been proposed to primary co-operatives. The amount lent to date is 47 Millions Ksh, at a negotiable interest rate between 15 and 18%. The beneficiaries are in total 984 members and the primary co-operatives channel the loan to the farmers. Because the union deals with both dairy and pyrethrum activities, not all the loans were directed to dairy activities.
Source: District Co-operative office in Kiambu.

Box 5: Getting a loan from a co-operative to start dairying: the example of Thyaka in Machakos district
The farmer is member of a coffee co-operative. He used to have indigenous cows, then he got to know that the coffee co-operative proposed loans to buy grade cows. He applied and took a loan, which he paid back progressively to the coffee co-operative. The co-operative directly deducted the repayments from his coffee and milk sales.

2.3. Other institutions

The third channel is to get a loan through projects, like the National Dairy Development Project (NDDP). The project was a collaborative project between the governments of Kenya and the Netherlands, with the objective to "meet the Nation wide demand for milk by introducing improved intensive dairy management practises on smallholder farms in high potential areas" (Ministry of Livestock Development 1990). The project started in 1980 to end in 1996. During the phase II (1982-83), two types of financial assistance were available to farmers willing to participate to the project: grants provided by the project and loans through a NDDP credit scheme. A total of 553 farmers were reached during this second phase.

In box 6, the experience of Mwangi who got a loan for the NDDP to start dairying is presented.

Box 6: Getting a loan from a project to start dairying: the example of Mwangi in Maragua district
The farmer was a "contact farmer" in the NDDP. He bought his two first grade cows at the time of the project. The project gave him a loan to build the "zero-grazing unit", so that the cash he got from selling his indigenous cows was enough to buy two grade cows. The farmer has currently two animals, one milking cow and an in-calf heifer, both Friesians. The cow gives 30 litres per day, quite a good performance compared to the smallholders' average production in Kenya. The zero-grazing unit is well built and maintained.

3. The theoretical model and its predictions

In this section, the theoretical model is presented and predictions are derived, either formally for the access to credit or intuitively for the other factors. The theoretical model identifies formally the factors that have to be introduced in the empirical analysis.

3.1. Formulation of the problem

The decision to engage into dairying is the result of many factors, some depending directly on the farmer (e.g. looking for alternative sources of income or increasing the farm income), some other beyond its control (e.g. milk price). Each "story" of dairy adoption is different, depending on the farmer's specific constraints and opportunities. The model can thus only take into account the most important factors that drive a farmer to enter into dairying.

The benefits (revenues) from the dairy enterprise that are retained in the modelling are the following:

a. sales of milk. Milk sales have an advantage over sales from other farm activities, because they are daily and relatively constant throughout the year, if the herd is well managed (since the farmer needs at least one milking cow throughout the year). The farmer may also be paid after a specified period (fortnightly or monthly) and this is usually praised as a means to save money.
b. production of manure. Manure is an important by-product of the dairy activity. In fact, farmers try to compensate the loss of fertility of their plots through application of manure. This is important in some areas under study where subdivisions of land between sons resulted in small and fragmented parcels. The importance of taking into account by- products in the analysis of the adoption of agricultural technologies has been put forward by Traxler and Byerlee (1993) in the case of modern cereal varieties in South Asia. When the differential in the production of straw (between the traditional and modern varieties) is introduced, it may not be profitable for a specific farmer to adopt even if the differential in the production of grain, which is the main output, would induce her to adopt.

The costs of dairying are the following:

a. the entry cost, which is the initial cost of the animal. Purchasing a grade cow is very expensive and for the farmers who cannot benefit from a "network" as described in chapter 2, the entry cost has to be met either from credit, from savings or from off-farm income. In the model presented in this chapter, the dynamics of savings and borrowing to pay for the animals have not been introduced; in other words, the model is fundamentally static and focuses on access to credit. Chapter 4 presents a more complete model where the dynamics of adoption are introduced.

   The costs of animals are modelled as a yearly repayment of loans. The model thus shows the "ideal" situation whereby the farmer does not bear the full cost of the purchase in one year, because she has access to credit. However, the interest rate is allowed to vary, thus mimicking imperfect credit markets.
b. the risks associated with animal diseases since grade cows are very sensitive to tick-borne diseases. These risks entail substantial costs, in terms of prevention and treatment, and risks of losing the capital if the animals die.

c. The risks associated with milk marketing. Since milk is a bulky and perishable product that needs to be sold daily, a reliable outlet is assumed to foster smallholders' adoption of high-yielding cows.
d. dairying requires labour every day. Contrary to crops, livestock requires daily care for feeding and milking.

Without dairying, the farm profits are equal to the profits from the different crops. In case of adoption the modelling takes into account the interactions between crop activities and livestock activity through the production of manure.

3.2. The labour market

Dairying (and livestock activities in general) requires labour every day, throughout the year. Moreover, supervision of hired labour in essential for dairying because of the care needed when looking after the animals. As a consequence, hired labour is assumed to be more expensive than family labour because of the supervision costs: $w_{cattle}^{hired} = w_{cattle}^{family} + s$ where w_{cattle}^{hired} is the effective wage rate paid to a hired worker, w_{cattle}^{family} the wage rate for family labour for dairy activities and s represents the supervision costs. Supervision costs are function of the number of hired workers and are increasing at an increasing rate: $s = s(L_{cattle}^{hired})$ with $s' > 0, s'' > 0$.

Another characteristic of the labour market is that women labour is less costly: $w^{w} < w^{m}$ where w^{w} represents the wage rate for a female worker and w^{m} the wage rate for a male worker. Wage discrimination against women is widely observed, both in Developed and in Developing Countries. In fact, some studies have shown that the wage gap between men and women cannot be fully explained by differences in education level and other workers' characteristics (Appleton *et al.* 1999; Brydon and Chant 1989). Data from the survey used in this analysis show that the wage rate paid to female (casual) labourers is lower than the wage rate paid to men (casual) labourers. The women average wage rate is 104 Ksh[3] per day *versus* 123 Ksh paid to men; the difference is statistically significant at 5%.

For crop activities, the labour market is assumed to be perfect between family and hired labour (labour is remunerated at the same rates, w^{m} for the men and w^{w} for the women): there are no supervision costs.

[3] The exchange rate was approximately US$1= 60 Ksh at the time of the survey (1998).