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Conditions d'Accès à l'Elevage Laitier
Le Cas des Petits Exploitants au Kenya

**(Adoption of Grade Cattle Technology in Kenya: a
combined Farm-level and Spatial Approach)**

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Nganga was rich. He had land. Any man who had land was considered rich. If a man had plenty of money, many motor cars, but no land, he could never be counted as rich. A man who went with tattered clothes but had at least one acre of red earth was better off than the man with money.

NGUGI WA THIONG'O

Weep not, Child

A mes parents,
Pour leur soutien

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Abstract

The dissertation aims at identifying the determinants of the adoption of grade cattle technology in the specific case of the Kenyan smallholders. Adoption of high grade cows by smallholders is driven by the objective of increased milk production, for both home consumption and sale. Smallholders are believed to have a comparative advantage in rearing grade cows, but constraints to adoption are numerous: the cost of a grade cow is relatively high, and the dairy enterprise is risky. Risks include animal diseases and lack of reliable marketing outlets. Marketing risks are a common preoccupation for smallholders but it is particularly relevant for milk, which is bulky, highly perishable and needs to be sold daily.

The main constraint to adoption is considered to be the entry cost and farmers have several ways to finance it. The author participated actively to the collection of survey data in several areas of Kenya that represent a broad range of levels of dairy productivity potential and market access. Two main analyses of the decision to rear grade cows were conducted, both theoretically and empirically. The first approach is static and analyses the decision at the time of the survey. The second approach uses a dynamic and spatial framework. GIS-derived distances are computed and introduced in a duration model in order to control for market access. Time is expected to play a key role in adoption and two time dimensions are introduced: an idiosyncratic time describing the conditions faced by the household at the beginning of the spell and historical time accounting for the changes in the external conditions. Results show that poor access to credit cannot be excluded as a reason for delaying adoption of grade cows. Policy changes over time are also found to play a role in the adoption process, as the reduced availability of reliable market channels and livestock services after liberalisation in 1992 are shown to have shifted down the adoption function.

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Introduction

Shedrack is a young farmer. He stays with his family in Machakos district, at 75 kilometres away from Nairobi approximately. With his wife and their two year- old daughter, he shares his parents' farm with his older brother. Like the majority of the farms in the area, Shedrack's farm has no piped water and no electricity connection. In a stall built next to his house, the farmer keeps his three Friesian cows and two calves. The presence of these strong and healthy animals contrasts markedly with the rest of the compound and especially the traditional house. For Shedrack, rearing dairy cows is very important. He invested in horticulture some years ago, French beans and tomatoes. With this activity, he managed to save enough money to buy his first grade cow. For him, dairying is "better" than horticulture because it provides him with frequent cash from milk sales and with manure that he applies to his coffee trees and food crops. Because the area is quite distant from the main road, there are few options to market milk. There is no dairy co-operative in the neighbourhood. So, Shedrack and some of his neighbours created a self- help- group in order to collect and market the milk produced on their farms. That was three years ago. Now, the group provides artificial insemination services as well; one of the farmer has been trained as inseminator and the group invested in cooling equipment. Shedrack has one wish: to save enough money to buy another cow and increase his dairy activities.

Shedrack's story is an example among others. For many farmers in Kenya, dairy farming represents a real opportunity to increase farm revenues. While the benefits of dairying can be substantial, few development programmes have considered dairying as a central means to improve African smallholders' standards of living and to decrease poverty. Understanding the adoption process of grade cattle technology in Kenya helps to identify the reasons for this "success story" (as Walshe *et al.* (1991) describe Kenyan smallholders' dairy sector), as well as the constraints that hinder the activity. Conditions under which dairy farming is a profitable activity for the African smallholders can then be derived.

The case of smallholder dairy farming in Kenya contrasts with the general observation on the relatively low adoption rates of agricultural innovations by African farmers (Binswanger and Pingali 1988). Dairy farming here refers to the dairy (or grade) cattle keeping where dairy cattle

represent the pure breed European cattle (or "high- grade cattle") and their crosses with traditional African breeds.

In Kenya, the experience in dairy farming from large-scale European farms during the colonisation has been successfully used to promote smallholder dairying after Independence. Other measures, particularly the creation of dairy co-operatives (to collect and market milk) and government investments in the provision and organisation of livestock services (artificial insemination, veterinary and extension services) facilitated the smallholders' entry into dairy farming. However, the proportion of dairy farmers varies widely across agro- ecological zones as expected since the profitability of dairying differs, but also within agro- ecological zones. The objective of this dissertation is to identify the opportunities and constraints of smallholders' acquisition of grade cattle technology in Kenya.

Why analysing smallholders' dairy farming in Kenya?

Total world milk production is evaluated approximately at 560 Million tons in 1998, of which less than 40% is produced in the Developing Countries. Milk production in Africa is particularly low: Africa produces less than 11% of the total production of the Developing Countries while representing more than 15% of the population (FAO databases). Moreover, animal productivity (milk production per animal unit) is lower in the tropical zones of Africa, compared to Asia and Central/ South America (de Leeuw *et al.* 1999). Within Africa, the diversity of production systems and productivity levels is also large. The dry zones and the Highlands are traditional cattle keeping areas while dairying is constrained by tick- borne diseases and trypanosomosis in the more humid lowlands. More than half of Sub- Saharan Africa milk is produced in East Africa (FAO databases, three- quarters according to de Leeuw *et al.*) and milk yields are more than twice the levels recorded in the rest of the continent. This is mainly explained by the high yield of local cattle in the Sudan (approximately 30% of total milk production in Sub- Saharan Africa) and the contribution of the intensive dairy production systems in Kenya (approximately 15%) that are analysed in this dissertation (FAO database and de Leeuw *et al.*).

The motivations to analyse the smallholder dairy sector are linked to the potential impacts that are expected from the activity¹: increased and regular income from milk sales; increased labour opportunities and positive impact on soil fertility maintenance. These points are now detailed.

¹ This section draws mainly on a "note for discussion" by S. Staal, ILRI- Nairobi, 1997.

In Kenya, the dairy sector constitutes the major source of livelihood for 625 000 smallholders (Omore *et al.* 1999). The activity generates increased revenues from milk sales and may offer a viable alternative to the production of traditional cash crops. In fact, the income generated by dairying is regular since the producers are generally paid on a monthly basis. This contrasts markedly with the sale of coffee and pyrethrum for which the farmer is paid on an annual basis. By increasing farmers' income, dairying has a positive effect on rural capital accumulation. Moreover, there are good prospects for a sustained demand for milk because of the rapid population growth coupled with urbanisation (Staal and Mullins 1996). The income elasticity of demand for milk is high (higher than traditional food crops), so there is a real potential for an increase in demand and real prices. Milk is an important component in the diet of Kenyans, especially in tea, and for all the classes of population.

The second positive impact of dairying is related to labour. Dairying is labour intensive, especially at high levels of intensification: labour is needed for preparing animals feeds, feeding and milking the animals. Dairying thus provides employment for the family members. Moreover, there are derived secondary positive impacts: the increased labour demand on dairy farms may be filled by hiring external labourers and the increased demand for livestock- related inputs triggered by dairying is beneficial to the whole rural communities.

The third effect concerns the effect of dairying on the soil fertility maintenance. Dairying contributes to the sustainability of smallholder crop-livestock systems by recycling nutrients, by increasing the availability of existing nutrients (with manure) and by enabling the storing of nutrients until needed through the storing and composting of manure (Nicholson *et al.* 1998). This role is particularly relevant in the areas where human population pressure on land is high and caused by the traditional sub- divisions of land between the household head's sons. While in extensive agro- pastoral systems livestock may be seen as a threat to the land long- term sustainability, the contrary applies in the studied case, i.e. in the mixed crop livestock systems.

Besides the above positive impacts of dairying on farmers and communities' welfare, the possible effects on the most poor and on women are mixed. In fact, the most poor may be unable to enter into dairying since the entry cost (the cost of the first grade cow) is high. And some dairy activities require collective organisations that co-ordinate milk marketing and the delivery of livestock services (Staal *et al.* 1998). The most poor may be excluded from this trend, although the creation of spontaneous "self- help- groups" may provide similar services to this class of farmers. Finally, the impacts of dairying on women are mixed as well. In many African societies, women are responsible for milk- related activities. The issue is whether they benefit from increased income generated by dairying in proportion of their labour supply. Evidence from

Mullins *et al.* (1996) is mixed since income from dairying increases in proportion of their labour supply only on farms where the extensionist is a woman.

Outline of the dissertation

The first chapter proposes an overview of the dairy sector in Kenya, with an emphasis on the opportunities and constraints to smallholders' dairy farming identified by the literature. The characteristics of the Kenyan dairy sector, compared to other African countries is highlighted, i.e. the important contribution of smallholders' milk output in the total milk production of the country. This specific case can be explained by the deliberate process followed at Independence by the government to transfer land and grade cattle from the large- scale European settlers' farms to the future population of smallholders. Moreover, the introduction of grade cattle by the settlers and the development of a dairy industry during the colonisation formed the basis of smallholders' dairying; at Independence grade animals were transferred to the Kenyan farmers and the needed technical know- how (especially in relation with the resistance of grade cattle to the environmental conditions) had been developed by the settlers. Reforms were however necessary in relation to the organisation of milk marketing and artificial insemination services.

The analysis of the economic literature on the adoption decision shows that the major constraint to the adoption of smallholders' grade cattle technology is the entry cost, i.e. the cost of a grade cow. In order to get the necessary liquidity, farmers have several options: using revenues from past agricultural revenues, using off- farm revenues and obtaining a loan. This last option is likely to facilitate the entry into dairying, thus identifying one way to induce farmers to adopt the technology if credit facilities are extended. Other constraints to adoption are the risks associated with animal diseases and particularly tick- borne diseases since grade cattle are more sensitive than local breed animals. The other important factor concerns the organisation of milk collection: since milk is a perishable and bulky product that needs to be collected daily, the milk collection of relatively scattered farmers has to be well organised in order to diminish the risk of milk spoilage. The chapter presents as well the survey implementation and the data used in the empirical analyses of the following chapters. The data were collected in two phases, in 1996 and 1998. The author participated to the second phase of data collection, enabling her to have control of the quality of the data collected and to get better insights of the constraints and opportunities of dairy farming by Kenyan smallholders.

As described above, the main constraint to the smallholders' adoption of the grade cattle technology identified by both the literature and field work is the cost of the first grade cow. The

analysis of the channels followed by the surveyed farmers to get their first grade cow shows that not all farmers actually purchased it: two other routes are then identified and their analyses constitute the topic of Chapter 2. The first route, besides purchasing, is to get the animal at no cash cost, as a gift from the family members or other networks. The second route is the progressive upgrading of local breed animals through crossbreeding using grade bulls or artificial insemination. The analysis of the two routes shows that the first one is highly farmer-specific and no general conclusions can be drawn. As far as the second route is concerned, very few farmers followed it and those are mainly farmers from the first generation after Independence. By consequence, the main route to acquire a grade animal is to purchase it.

Therefore Chapters 3 and 4 analyse the adoption decision in the specific case of farmers who did purchase their first grade cow. Note that the survey data does not provide the ways farmers used to finance the purchase. The issue of access to credit as a way to facilitate the adoption of grade cattle technology is treated in Chapter 3 in an original static model, which takes into account other factors that may influence the adoption decision. Results show that the hypothesis that access to credit facilitates the adoption cannot be rejected. However, the model is fundamentally static and does not consider the flows of savings from past agricultural activities and the modifications of the external conditions. The next step is then to consider the adoption decision not as a "snapshot" at the time of the survey but as a transition process. The analysis of Chapter 4 thus aims at identifying the factors explaining the length of time before adoption. The main hypotheses of the theoretical model are not rejected by the data. In particular, results suggest that the adoption rate has significantly slowed down after the liberalisation of the dairy sector. This trend is explained by the lower incentives to adopt given the collapse of dairy co-operatives in some areas and the withdrawal of government livestock services following the liberalisation. This result calls for interim support for farm services and market mechanisms to maintain technology adoption trends.

The last chapter deals with the level of intensification in dairy farming. The analysis is thus the logical prolongation of the previous chapters since it deals with the level of productivity after the acquisition of a grade animal. The analysis is constrained by the fact that the level of milk production has to be estimated in a first step in order to derive an unique indicator for the intensification level, which is the level of milk production per farm per year per unit of land. The analyses show that there are two main factors at play: the land size owned by the farmer and the availability of livestock services. Using the main indicator for the intensification level, results show that farms with limited land size are more intensified, *ceteris paribus*. The analysis is then

developed further by distinguishing two means through which a farmer intensifies her dairy activities: by increasing the number of cows kept on the farm and by increasing the individual cow productivity (milk yield). Results show that milk yields are not influenced by land size, suggesting that land size is not a prerequisite to reach high levels of cow productivity. A second important result concerns the availability of livestock services in the neighbourhood that stimulates the dairy enterprise productivity. A similar conclusion to the one relative to the analysis of the adoption process can thus be drawn: the availability of livestock services is a crucial factor for the smallholders' dairy sector, both by inducing farmers to enter into dairying and by increasing the productivity of the dairy enterprise after adoption.

Chapter 1

Dairy farming in Kenya: an overview

1. Introduction

Dairy farming is an important sector of the Kenyan economy, generating substantial income for the smallholders that produce more than half of the total milk production in Kenya (Omoro *et al.* 1999), welfare through milk consumption and employment opportunities in the rural and peri-urban areas. This first chapter aims at presenting the key features of the Kenyan dairy sector, some historical background and smallholders' opportunities and constraints in dairy farming. Of note is the fact that the Kenyan dairy sector is changing rapidly with the progressive liberalisation of veterinary services since the beginning of the 1990s, the liberalisation of the milk marketing in 1992, the entry into milk marketing of private dairy processors and the growing importance of small traders in the smallholders' milk marketing (Staal and Shapiro 1994, Owango *et al.* 1998).

The agricultural setting under study is a mixed crop-livestock system, dominated by white maize production often intercropped with beans. Other food crops are kale (cabbage), potatoes and bananas. Some farmers derive an important part of their revenues from the sale of cash crops: tea, coffee and pyrethrum. Almost three-quarters of the surveyed agricultural households keep cattle, of which approximately 65% have cross-bred or high grade animals. Cattle-owners keep on average 2 cows (median of 1 cow) on 2.5 hectares (median of 1.4 hectare).

The second section of this chapter provides some key data on the dairy sector and the important contribution of smallholders in the total milk production and marketing, which is a unique situation in the East Africa region. Section 3 explores the beginning of dairy farming in Kenya and shows how European settlers provided a stepping stone for the future development of dairying in the country. Today's constraints and opportunities are analysed in section 4 using the literature on adoption of agricultural technologies in developing countries from different fields of research (economics, sociology and animal science). Section 5 presents the area under study and the data that will be used in the empirical analyses of the subsequent chapters. Section 6 finally concludes on the constraints and opportunities offered by dairy farming to the Kenyan smallholders.

2. The dairy sector in Kenya

The dairy sector constitutes an important component of Kenyan agriculture since it occupies about 47% of Kenya's arable land (Government of Kenya 1986 in Ngigi 1995) and provides the major source of livelihood for 625 000 smallholders (Omore *et al.* 1999). The contribution of the livestock sector in the agricultural GDP approximates 30% in 1995. Livestock products represent 13% of gross marketed agricultural production and are composed mainly of animals for slaughter and dairy products. Formal marketed production of dairy products represents less than 4% of the livestock marketed production, but this figure is underestimated since it does not include the informal sales of dairy products and particularly raw milk that are dominant in this sector (Statistical Abstracts 1995 and 1996). By comparison, Peeler and Omore (1997) estimate that total milk production constitutes approximately 50% of the total value of all livestock products.

Since no recent livestock census data are available, only estimates are possible. Cattle population is estimated at 12,9 millions, of which 3 millions are dairy cattle and 9,9 are traditional Zebu animals (Peeler and Omore). The terms "dairy cattle" or "grade cattle" represent the *Bos taurus* cattle (pure breed European cattle or "high- grade cattle") and their crosses with traditional breeds². Dairy cattle are concentrated in the medium and high potential agro-ecological zones of the Rift Valley and Central provinces while Zebu cattle are more widely distributed; maps in annex 1 present the distribution of cattle in Kenya. Of note is the fact that about 60% of the milk in Kenya is produced on less than 10% of the country's landmass where 80% of grade cattle are kept (Omore *et al.*).

Milk production is estimated at 3,076 million Kg per year, of which 56% come from the smallholder dairy herds. The table 1 details these data by distinguishing between large and small-scale systems on the one hand, and traditional Zebu and dairy cattle on the other hand.

Table 1: Cattle population and milk production, by system

Systems	Cattle population	Milk production (Kg per year)
Large scale dairy cattle	500,054	782,314,884
Small scale dairy cattle	2,544,677	1,719,202,961
Large scale traditional Zebu cattle	4,482,570	245,971,740
Small scale traditional Zebu cattle	5,348,501	328,280,855
Total	12,875,802	3,075,770,441

Sources: Peeler and Omore, 1997.

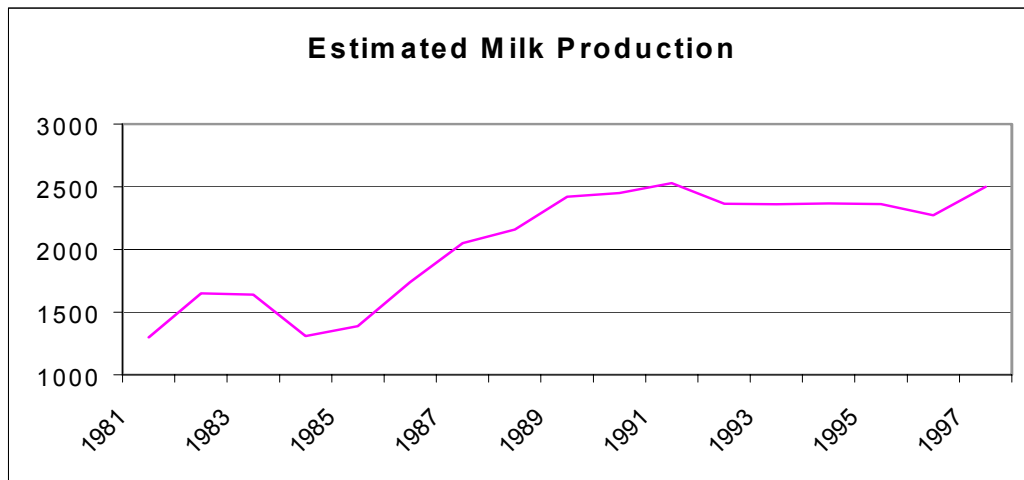
² Cross- bred cattle is a wide category since the proportion of "exotic" or "dairy" genes is left unspecified. However, during the data collection, an animal was registered as cross- bred if the percentage of dairy genes was at least equal to 50%. Animals with less than 50% of dairy genes were registered as "local breed animals".

Of note is the fact that the small scale dairy sector keeps almost 84% of the total dairy cattle but produces less than 69% of the milk produced by the dairy herd. The relatively poor production performances recorded on smallholders farms are mainly explained by the lower quantity and quality of feeds offered on these farms, compared to large- scale farms.

Graph 1 below shows the evolution of milk production (in millions of litres) from 1981 to 1997. The trend is upward up to the beginning of the 1990s when the production started stagnating. However, this trend may not reflect the exact situation since Peeler and Omore report positive herd growth in all cattle production systems, especially the dairy herd. The authors suggest that the observed stagnation is due to the lack of census reports on which to base cattle population; the same estimates may thus have been used.

Of note as well is the effect of the weather conditions on the milk production: the three droughts in 1984, 1992 and 1996 appear clearly.

Graph 1: Estimated milk production (Millions of litres): 1981- 1997



Sources: Government of Kenya, 1997.

Within the two main sectors (small- scale and large scale), there is a large heterogeneity as detailed in table 2:

Table 2: Production systems in dairy farming in Kenya

	Large scale		Small scale		
Production System	Intensive and Semi- Intensive	Extensive	Intensive and Semi- Intensive	Semi-Intensive	
Genotype	Exotic/ Crosses	Zebu	Exotic/ crosses	Zebu/ crosses	
Major Products	Milk	Milk & meat	Milk & manure	Milk, meat, draught & manure	
Agro-Climate	Humid to semi-humid	Semi-arid to arid	Humid to semi-humid	Humid to semi-humid	
Purposes	Market- oriented	Mostly pastoralism	Market-oriented	Mostly subsistence	
Cattle Population	'000 %	500 4	4,5 35	2,5 20	5,3 41
Milk Production	'000 MT %	782 25	246 8	1719 56	328 11
Major Production Regions	Central Rift Valley	North and south Rift Valley, Eastern and Coast	Central Province, Central Rift Valley and Coast	Nyanza, Western, Coast, Eastern and Rift Valley	

Source: Peeler and Omore, 1997.

The most extensive system is mainly based on local Zebu cows which are grazed on communal land. Farmers keep large herds of local breed animals, but total milk production is very low. This system is found in arid and semi- arid areas, including Masaai land.

In the other zones (humid and semi- humid), different systems co-exist (Chema). Besides the large scale system that is not included in this analysis, there is a continuum of production systems from low intensive to high intensive systems. The low intensive system is based on cross- bred cows grazed on natural and extensively managed pasture; the moderate intensive system uses higher grade cows which are grazed on well managed or cultivated pasture land. The third system or semi-zero grazing system is a high intensive system which rears pure exotic or high- grade cows; animals are partly grazed on natural or cultivated pasture and are supplementary fed with arable fodder crops and concentrates. The most intensive system, or zero-grazing system, keeps pure exotic dairy cows which are kept in stall or confined area where they are mainly supplied by fodder crop which are cut and carried to the animals; concentrates are also fed. An additional class is landless urban milk producers who depend on purchased feeding but who can benefit from a high sale price for their milk through the informal milk market.

3. The introduction of high grade cattle in Kenya: the experience of the European settlers

3.1 Origins of dairy farming in Kenya

The majority of the ethnic groups in Kenya traditionally keep cattle. Using historical data, Ouma *et al.* (1999) show that cattle have traditionally been kept not only for milk and meat but also for draught power, manure, prestige, marriage dowries and sacrifices. In Central Africa, South Western Africa and Northern Africa (nomadic pastoral systems), cattle density is relatively low (at 0-5 heads of cattle per km²). On the other hand, high cattle densities (10 to above 100 heads of cattle per km²) are found in Eastern Africa (and especially the highlands of Kenya, Uganda and Tanzania), South - Eastern Africa as well as in Madagascar. Cattle kept traditionally were local breed Zebu animals that are well adapted to the prevailing agro-ecological conditions and resistant to tick-borne diseases that are widespread in the area.

At the beginning of the 20th century, high-grade cattle were introduced in the Kenyan Highlands by the European settlers but these animals were highly susceptible to the local endemic diseases, especially tick-borne diseases and many succumbed. The strategy was thus to crossbreed the grade animals with indigenous cattle, resulting in high-yielding animals that were more disease resistant than the pure exotic breeds. Crossbred exotic bulls were then used to upgrade local cows. Another problem arose with the progressive death of the exotic bulls and artificial insemination services were then introduced, making Kenya the second country in the world to use artificial insemination services after Russia. Semen was either imported or collected from bulls kept in protected camps. Livestock support services (control of livestock diseases and animal husbandry extension) were initiated (Omore *et al.*). Ownership of grade cattle was however strictly reserved to Europeans whose overall goal was to produce butter and cheese, mainly for exportation. In 1925, (European) dairy farmers, under the leadership of Lord Delamere created the Kenyan Co-operative Creameries (KCC) (Metz *et al.* 1995). The primary goal of KCC was to federate the dairy farmers into a common organisation responsible for regulating the marketing of butter, locally and for exports (Ministry of Agriculture 1965 or Kibaki report). During the Depression, the co-operative lobbied to obtain protection against competitive imports and to restrict potential competition from African farmers. In 1950, the KCC began to market fresh milk in Nairobi and Sotik in Kericho district.

3.2 A turning point: the Swynnerton Plan in 1954

In 1954, the Swynnerton Plan advocated the development of African small-scale farming, especially cash crops and improved livestock breeds (Ngigi 1995). Smallholder Kenyan farmers were then entitled to keep dairy animals but they usually lacked the needed cash to engage into dairying. As Heyer (1976) noted, few farmers obtained loans despite the introduction of land title deeds to be used as collateral. Moreover, Kenyan farmers had to meet certain conditions to be allowed to purchase a grade cow (Conelly 1998 and Waithaka 1998): the landholding had to be consolidated (i.e. reallocation of scattered parcels into a single consolidated plot); the farmer had to follow some livestock management practises (proper fencing to separate the grade animal from other livestock to reduce the risks of diseases, planting a sufficient area with improved grass, adequate internal supply of water, etc..) and a minimum size requirement was set. However, some Kenyan farmers purchased dairy animals directly from European farms without government approval (Conelly, p. 1743), thus without control of such conditions.

Despite the high cost of purchase and the conditions required to start dairy farming, progressive transfers of ownership of grade cattle started before Independence. Jaffee (1993) details the measures that facilitate smallholders' adoption of grade cattle technology:

- Land titling programs were organised, along with a smallholder credit project financed by the Kenyan government and donors. At Independence, African people benefited from massive land transfer from the European settlers who opted to leave the country.
- The simultaneous growth of tea, coffee and pyrethrum production by smallholders provided them with capital to purchase the grade cows, as well as boosting the demand for milk.

Because of the difficulties to acquire a grade cow, the numbers of grade cattle owned by Kenyans were relatively limited before Independence (Conelly); almost all the grade cattle population belonged to the European large-scale farmers (420,000 head according to Chema). After Independence, the change in the ownership of grade dairy cattle was dramatic: Chema estimates that in 1970, 60% of the dairy herd was kept on smallholder farms.

With smallholders' entry into dairying, the main difficulty was to organise the collection of the milk in a country where rural homesteads are relatively scattered. In the mid-1950, farmers' co-operatives were created to overcome this issue and in the late 1950s, KCC began to market milk from the smallholder co-operatives. The issue of organising a milk collection network is analysed further in section 4.3.

3.3 The settlers' experience as a learning externality

Some Kenyans, mainly Kikuyu, were employed on European settlers' farms where they learned the rudiments of cattle rearing (Conelly 1998 and Waithaka 1998): this can be interpreted as a learning externality whereby the settler's experience/experimentation has an influence on the Kenyan farmer's knowledge of the new technology.

To paraphrase Ryan and Gross (1943), the settlers offered a "community laboratory" to the future Kenyan dairy farmers. Ryan and Gross are the first authors who analyse the adoption process in agriculture. Their study concerns two communities in Iowa and deals with the adoption of maize hybrid seeds from 1934 to 1942. Few farmers used the new seeds on the entire farm the first year. The explanation proposed by the authors is that the first adopters provided a "community laboratory" to their neighbours. In the case of the Kenyan dairy sector, the settlers' introduction of high grade animals in the Kenyan Highlands and the use of cross-breeding to reduce the risks of animal diseases constitutes an experimentation which benefited the future generations of farmers, Kenyan and European.

Besley and Case (1994) and Foster and Rosenzweig (1995) have explored the issue of learning externalities. In Foster and Rosenzweig's model, the authors test for the existence of learning spillovers in the case of the adoption of high yielding variety seeds in India during the Green Revolution using panel data. The optimal use of inputs is assumed to be unknown and stochastic. In their model, learning enables the farmer to increase the profitability of the new technology through a more efficient use of fertilisers.

When deciding to adopt or not, a farmer may exhibit a strategic behaviour in the sense that it may be in her interest to wait and see what the others do before her own adoption. It means that the neighbours' characteristics belong to the farmer's decision rules. The adoption decisions are assumed to depend on the farmer's past decisions, on neighbours' past decisions and on expectations for the future.

The model distinguishes between three types of learning from others:

- there is no learning from others: neighbours' characteristics/assets have no effect on the adoption decision;
- the learning externalities are internalised: the effects of the neighbours' assets are equal to n times the effect of farmer i 's own assets (with n representing the number of neighbours);

- the learning externalities are not internalised: if the returns to experience are decreasing, the farmer i has an incentive to free-ride and to adopt a behaviour of "wait-and-see". In that case, there is a negative relationship between the neighbours' assets and farmer i 's adoption decision.

The results of the empirical analysis show the existence of learning spillovers between neighbours, yet the effect is low. Moreover, there is some free-rider behaviour whereby farmers do not co-ordinate the decisions to adopt the improved seeds. Since such co-ordination would induce socially more efficient learning process, the authors propose a subsidy policy towards the early adopters in order to "reward" them. In the case of the adoption of grade cattle technology, the fact that the settlers had the monopoly of keeping high-grade cows and selling milk can be interpreted as a subsidy that induced them to experiment and to adapt the dairy technology to the Kenyan conditions.

Nowadays, smallholders dominate milk production in Kenya. The opportunities offered by dairying and the constraints faced by smallholders are presented in the following section.

4 Opportunities and constraints of dairy farming in Kenya

4.1. Smallholders' opportunities in dairying

4.1.1. Increased milk production

While the entry cost into dairying is high, the level of milk produced by a grade cow is expected to be seven times that of a local (or Zebu) cow, *ceteris paribus* (FAO 1991). The local breed animals found in Kenya include essentially the East Africa Zebu (thereafter called Zebu). The Zebu cow is small and is mature at around 3.5 years. On average, milk production reaches 200 kg per lactation. By comparison, a high grade cow reaches maturity at around 2.5 years and the milk production per lactation varies between 2400 and 3000 kg under good management and appropriate feeding. Crossbred cows reach intermediate production levels, at around 1400 kg per lactation. Of note is the fact that levels of production reached on smallholders' farms are below genetic potential: some estimations show that with better feeding and management, the production can be increased by at least 50% (FAO, p. 3).

Using the survey data that are described in section 5 of this chapter, local breed cows produce on average 485 kg of milk per lactation; the calculation is based on 81 cows using a production function approach as explained in Chapter 5. For a crossbred or a grade cow, the average milk

production per lactation is 2313 kg (results based on 278 animals): the results are thus relatively consistent with the FAO data. Based on these results, a grade cow (be crossbred or high grade) produces almost five times more than a local breed cow, thus providing a productivity incentive for farmers to enter into dairy farming, *ceteris paribus*.

When considering profits derived from dairy activities (and not only levels of milk production), previous studies have shown that dairy farming generates positive profits. A team of Egerton University (Kenya) analyses the profitability of smallholder dairy farming in Kenya in different areas and under different management practices. Results show that total profits are positive in all cases, enabling the authors to conclude that such profits "correspond with the keen interest among Kenyan farmers to participate in dairying", and despite the gradual decline in the real producer price for milk observed before and during the period the study took place (Egerton University, 1990). Similar conclusions are drawn from a study by Staal and Shapiro (1994) who report positive producer net profits (including cost of land and labour) in Nyeri district (Kenya) after the milk market liberalisation in 1992.

4.1.2. Labour availability and human capital

Dairying is a labour-intensive activity: tasks like collecting fodder, feeding the animals and milking require labour daily. Smallholders are described to have a comparative advantage in rearing grade animals because of the labour and personal attention required (Walshe *et al.* 1991). However, farmers with limited family labour may find it difficult to meet the labour requirement of dairy farming.

Human capital is represented by experience and schooling. Dairying requires acquiring a specific knowledge, especially on feeding strategies and diseases controls (Brumby and Gryseels 1984). Extension efforts are sometimes seen as a substitute for education. The literature shows that farmers with better education or who are visited by extension services are early adopters, or adopt more. In fact, "educated farmers are more able to manage new technologies or they became aware of productive innovations at earlier stages of growth than their less- educated counterparts" (Foster and Rosenzweig 1996 p. 951).

Rahm and Huffman (1984) point out that results on education level may not always be consistent with the expectations. In fact, education may have a negative effect on the adoption decision if the new technology is not economically feasible since non- adopting is the best option.

Another point of note concerns the possible endogeneity of the variable representing the number of visits by the extension services to the farmer (Strauss *et al.* 1991). In fact, it is possible that visits are not randomly distributed among the farmers population but that the farmers who are the more willing to adopt receive more extension services visits. In that case, there is a selectivity bias that the econometric estimation needs to address.

4.1.3. Learning by doing

The adoption process can be defined as "the mental process an individual passes from first hearing about an innovation to final adoption" (Rogers 1962 cited by Feder *et al.* 1985). Learning is an important component in the adoption process, as several models of adoption emphasise. Using panel data to analyse the adoption decision of high yielding variety cotton seeds in India, Cameron (1999) shows that learning through experience is an important determinant of the adoption decision.

In Hiebert's model (1974), the adoption decision is taken as a decision problem with uncertainty: potential adopters have incomplete information on the characteristics of the innovation. In the case studied by Hiebert, the innovation consists of improved seeds, and the farmer does not know exactly the effect of fertiliser on production. During the adoption process farmers accumulate information that progressively decreases uncertainty; fewer allocation errors are then made. Moreover skills enable the farmer to decode information. The production function thus includes a parameter β which represents the state of nature whose informational state varies with the farmer's experience. During the process the farmer accumulates information on the unknown parameters and modifies the input levels so that the profits probabilities are redistributed toward higher values. That means that the revenue distribution function moves to the right as the learning increases. Depending on the information they possess, farmers exhibit different adoption behaviour: the likelihood that a particular farmer adopts increases with her information stock. Since the skills are used to better understand the available information, the conclusion is that the adoption probability increases with the farmer's skills.

Like the previous one, Kisley and Shchori-Bachrach's model (1973) highlights the importance of the skills in the adoption process. In this model, adoption is function of comparative advantages: the first firms to adopt are the ones with experience and good capacities, then there is a diffusion process and less skilled firms adopt as well. As more firms adopt, the supply raises and the sale price decreases progressively. In that case the "leaders" firms stop the production since it is less profitable; a second production cycle takes place.

In the mathematical formulation, the authors introduce a multiplicative term, g , which represents knowledge. The term g is an increasing function of both the entrepreneur's skills (and thus of her opportunity cost of labour) and the experience in the industry (approximated with the cumulated output of the new production). The conclusion of the model is that the adoption process begins with the firms which are "capacities intensive".

By comparison with the Kisley and Shchori-Bachrach's model, Feder and Slade's model (1984) includes two components to the knowledge: a "general" component, $g(K_i)$ where K_i represents the cumulated information and a specific component particular to the input, $b(K_i)$. Information comes from the same source and is thus represented by the same variable in the two components. The effect of knowledge by hypothesis increases at a decreasing rate. There is thus a level of knowledge from which g and b are constant. The particularity of the model is that farmers search information both passively and actively. Active research is costly and the costs increase at an increasing rate. It is thus possible to explain the observed lag between adoption by large and small farmers. In fact, during the initial period of diffusion it is expected that large farms are more able to put resources into information searching; in that case, large farmers have a higher cumulated information stock. Farmers with better access to information are comparable to the large farmers. The conclusion is that large farmers and the farmers with better access to information are the first to adopt since they can spend more resources or are more efficient on information gathering.

The bayesian approach analyses explicitly the process of information accumulation. In the Feder and O'Mara (1982) model, farmers use the available information to modify progressively their opinions on μ , the mean of profits of the new technology. Farmers are supposed to be risk neutral. A specific farmer adopts when her opinion on μ is higher or equal to the mean profits of the old technology. In that case, the adoption is higher the more profitable is the new technology and the less profitable is the old technology, *ceteris paribus*. During the initial diffusion phase the adoption rate does not depend on the profitability of the new technology but on the profitability of the old technology and the parameters of the distribution function of the initial beliefs regarding μ among the farmers. Of note in this model is that each farmer has access to the same information concerning the new technology, whether she has adopted or not.

Firms' beliefs regarding the profitability of a new technology are updated as a bayesian process in Jensen (1982) model as well. When the new technology is introduced, agents do not know whether it is profitable or not. This incertitude is reduced by waiting and by accumulating some

information. The agent's problem is thus an "optimal stopping" problem: either she adopts or she waits and sees.

The bayesian approach has been studied in more depth in an article by Grossman et al. (1977). The authors use a dynamic model that incorporates a bayesian mechanism to update the agents' expectations. The agent who receives some information realises that her future decisions will depend on the information she is collecting now by observing the consequences of her actual behaviour. She thus weighs up the advantages and the drawbacks. The advantages are that the future decisions will be based on better information; the drawbacks are that because of this experimentation, the agent's behaviour differs from the optimal short-term behaviour (where there is no possibility of learning-by-doing). In the article, the problem is to find the optimal consumption of medicines: the trade-off is between informational gains for the future and current health gains. The opportunity to experiment induces the agent to consume more, since this gives relevant information for the future. In the case of the adoption of a new technology in agriculture, a farmer may tend to adopt more or earlier if experimentation enables her to have informational gains in the future. In other words, farmers may adopt more or earlier in spite of uncertainty if the information which is gained by adopting now enables them to reach higher profits in the future.

4.2 The constraints to the adoption of grade cattle technology

4.2.1. The entry cost constraint

Starting dairy farming entails several costs: buying a cow, building a stall as well as getting equipment for milking and preparing the feeds for the animals. The most important cost is the purchase of a grade cow: a grade cow costs on average 14 times the monthly wage of a rural male labourer (survey data). The cost of the first dairy cow (or heifer) is identified by Carlsson (1996) as the main constraint to dairy farming (with costs of veterinary services and feed purchases) in Arumeru region (Tanzania). For Leegwater *et al.* (1991) in a study taking place in the Kenya Coast, the "zero- grazing system", which includes the purchase of a grade cow and the building of a stall, is adopted mainly by the "rich" farmers because of the investment requirements (entry cost). In Nicholson *et al.* (1998), the principal reasons cited by the farmers for not adopting dairy cattle in the Kenyan Coast province are the "lack of money to purchase the animal" and "lack of credit".

In most cases, the literature on adoption of agricultural innovations in Developing Countries deals with the case of the adoption of high- yielding cereals varieties, such as in the "Green Revolution". The case studied in this dissertation assumes the existence of an entry cost that is not (or less) relevant in the case of the adoption of high- yielding cereals varieties. Few references will thus be used from this literature. Smale *et al.* (1994) provide a "complete" model to explain the differential rates of adoption of high- yielding cereals varieties across farmers.

Differential access to capital is often cited in the economic literature as an explanation for differential rates of adoption. Access to capital is related to farm size: households with large land size are expected to have better access to credit, *ceteris paribus* due to collateral and better access to information. Shortage of credit is reported by many studies as a major constraint to smallholder dairy farming (FAO 1991, De Boer 1999 and Government of Kenya 1997). There are some institutions providing credit to smallholders to start dairy farming, but many farmers do not meet the conditions to get a loan. The analysis of credit constraint and the specific case of Kenya is analysed in depth in chapter 3.

In the empirical studies, two important issues have to be raised. The first issue deals with the definition of the credit constraint and the conditions when it is binding. A household is considered credit constrained (i.e. the constraint is binding) if one of the two following cases applies: if it borrowed but indicates a desire for more credit at the current interest rate or if it did not borrow because it could not obtain credit. This definition follows the work of Feder *et al.* (1990) and Freeman *et al.* (1998). Variables to compute the household's credit constraint status are not always available in the surveys and borrowers are classified as non-constrained and not-borrowers as credit-constrained, which is misleading.

The second issue concerns a possible endogeneity of the credit constraint variable. In fact, there may be some unobserved (or unobservable) factors that determine both the decision to adopt the new technology and the credit constraint status. The analysis in chapter 3 takes this possibility into account by estimating in a first step the farmer's status on the credit market.

4.2.2. The risks involved in dairying

Feder *et al.* (1985) distinguish two types of risk when analysing the adoption process of an agricultural innovation: a subjective risk and an objective risk. There are subjective risks because the farmer is uncertain about the new technology. In the case of dairy farming, subjective risks arise because farmers are uncertain about the milk yield of the improved animals. On the other

hand, objective risks are due to well-known factors associated with the new technology: high-grade cattle are more sensitive to tick-borne diseases than local breed animals.

Risks in dairy farming depend on the type of system: animals confined in zero-grazing units are less exposed to the external environment and thus the chances to be infected by ticks are lower. On the other hand, animals free to graze on open fields have a higher likelihood to be infected by the vectors of the diseases.

In the Kenya Highlands, the main tick-borne disease is the East Coast Fever (ECF), which is an acute and often fatal disease transmitted by a brown ear tick. ECF can be prevented through application of acaricides either by dipping or hand-spray. However, the use of acaricides does not guarantee total prevention against ECF, therefore a disease outbreak cannot be excluded. Other tick-borne diseases are anaplasmosis, babesiosis and heartwater. The other major diseases that can potentially affect the herd are helminthiasis (high morbidity rates but low mortality rate), trypanosomiasis (transmitted by tsetse fly and sometimes fatal) and foot and mouth disease (K'Aluoch 1997).

Acaricides are applied either through communal dipping facilities or by hand spray on farm. In the past, communal dips were established and maintained by the government with donor assistance. Since 1991, the government handed over the maintenance of the dips to local communities with little success. In fact, the dipping facilities are not properly maintained in some areas, forcing the farmers to apply acaricides on farm. This method may not be feasible if there are many animals on farm and may give rise to health problems (Curry *et al.* in Sutherland 1999).

Because of the environmental differences between regions of Kenya, the incidence of tick-borne diseases differs widely depending on the location of the farm (Sumption *et al.* in Sutherland 1999). Factors affecting the geographical distribution of the brown ear tick are heat, dryness and vegetation cover.

Veterinary services can be used by the farmer to lower the incidence of diseases (through preventive measures) and to reduce the termination cases (through curative measures). Starting in 1966, efficient livestock services were provided to smallholders at a subsidised price by the government. Artificial insemination services were also offered at a low price (Omore *et al.*). The government support continued until the beginning of the 1980s when the delivery of the services diminished due to government budgetary constraints. Subsequently, the objective has been to transfer the provision of veterinary clinical services to the private sector.