Economic Constraints of Smallholder Milk Production in Kenya
A Linear Programming Approach

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Paper presented at the 37th Annual Conference of the Australian Agricultural Economics Society held at the University of Sydney, February 9-11,1993.

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ABSTRACT

This paper examines the major economic problems related to milk production in Kenya. Smallholders are not efficiently utilising resources to produce milk and other food crops. A Linear programming model is employed to investigate how resources can be reallocated among competing enterprises in order to maximise farm income. Three farm models are developed defining small, medium and large farms to identify the economic constraints related to each farm size. The result suggests that land and operating capital are the major limiting factors of production. Sensitive analysis is used to determine the stability of the optimal solution by varying the values of the limiting resources. Accordingly, changes in the land area and value of working capital have significant effects on milk production.

Introduction

Agriculture is the major contributing sector to the development o the Kenyan economy. Agricultural products account for thirty percent and forty percent of the gross domestic product and total export earnings respectively. Agriculture represents the ma source of employment in the rural areas, and about eighty t percent of the rural labour force is engaged in agricultura production. The agricultural industry consists of large and ma

scale farms1. However, the small-scale sector plays a major role in the growth of the Kenyan economy. About seventy five percent of the population derive their livelihood from small-scale farms (Central Bureau of Statistics 1990 a).

Substantial quantities of dairy products which are used for domestic and export markets are produced. Dairying accounts for about thirty five percent of the livestock exports. In 1989, sixteen percent of the total gross revenue was generated from livestock products. (Central Bureau of Statistics 1989 b). Smallholders produce about eighty percent of the total milk produced for domestic and export markets (Ministry of Livestock Development 1990).

The Kenyan government has realized the importance of dairying in economic growth, and has laid strategies for its development. Milk production is expected to grow by 5.1 percent and milk supply by 4.9 percent (Republic of Kenya 1984). However, the current milk production is low compared to the estimated 3.8 percent per annum rate of population growth (Tessema 1988). The low milk production is attributed to lack of improved management and husbandry (improved breeds of cattle, artificial insemination and better methods of disease control), pasture and grass land improvements, and improved nutrition feeds. There is no provision for dry season feeding, and animals tend to start lactating under very poor conditions (Kuiqu 1978).

This study will identify the major constraints which limit milk production in Kenya. A Linear programming (LP) model is used to investigate how smallholders can increase their farm income by reallocating scarce resources among competing enterprises within the existing farming condition.

Area of Study

The study is carried out in Embu district. Embu is the provincial town of the eastern province of Kenya. The district has areas of all the major agro-ecological zones, varying from higher potential area to non-agricultural zone. The total area of the district is 2,300 hectares (ha), of which 96 percent is suitable for agricultural production. The district produces cash and subsistence crops such as milk, coffee, maize, beans, potato and tomato (District Development Plan).

The district is not among the major livestock producers in Kenya. However, livestock production plays an important part in the district, particularly in the southern drier areas, with low rainfall and low potential land, where crop production is difficult due to unfavourable climatic conditions (Republic of Kenya 1985 b). The high potential area is suitable for dairying, and farmers keep grade and crossbreed cows. Zebu cattle which are heat tolerant and which yield very little milk are found in the drier areas, and are mainly used for beef production.2 The current milk production is very low compared to the domestic consumption requirements and this is due to lack of adequate feeding of dairy stock and low population of grade cattle.

Method of Analysis and Data Collection

The identification of the constraints at farm level is based on the sample survey result that was carried out in the district. The survey was carried out for a period of one year, covering the dry and flush seasons, and data were collected on dairying and alternative enterprises. The feasibility study of the area revealed that all locations in the district have a fairly homogeneous nature, in the farm size, farm type, farming practice, resource and constraints. The study concentrated on one location and the location was randomly selected. An attempt was made to make the strata internally homogeneous by placing in the stratum farmers with the same size of farms. The farms were stratified into three strata according to their sizes. A random sample of 60 farms were selected from these strata for detailed investigation.

Three farm models are constructed, representing small, medium and large farms. It is assumed that each representative farm has different natural endowments, hence each farm has a different production boundary.

The three representative farm models are as follows.

1. A representative farm of 2.04 ha. is developed representing small farm model (1.2 ha. - 3.5 ha.)
2. 4.9 ha. is designed to represent the medium farm model (3.6 ha. - 5.9 ha.)
3. 7.98 ha. is established for the large farm model (6.0 ha. - 8.3 ha.)

Optimal farm plans3 are developed using a linear programming model.

Parametric programming is used to test the stability of the linear Programming solution. This is carried out by investigating the changes that would occur when land is allowed to increase holding labour and operating capital constant. Similarly, labour and operating capital are allowed to vary holding land constant. This technique is useful to determine how the optimum combination of activities and the value of the objective function would be affected, when limiting resources are allowed to vary.

Theoretical Framework of the model

The model will maximise production subject to resource constraints and certain basic minimum and maximum requirements of the farmer. The resource constraints are labour, land capital and other factors which limit milk production.

In the analysis of agricultural problems, a linear programming model can be used to improve farmers' decision making. However, some scholars argue that it has certain limitations in its analytical techniques, particularly when it is applied to the problems of peasant farming. The usual objective function is the maximisation of farm income. Peasant farmers derive their household subsistence from the farm produce, and are concerned about the high degree of risk associated with their low level of income rather than cash income maximisation. Linear programming

does not include any allowance for such risk, and it may be difficult to determine the objective function under peasant farming systems. Other scholars have made an attempt to justify that there is no objective proof that peasant farmers are only concerned about their subsistence needs.

Low (1974) suggests that linear programming can handle a large number of inter-related variables. It is suitable for peasant farming systems, which are characterised by a high degree of inter-dependence between production and consumption, consumption and investment and social as well as cultural constraints. He further argues that appropriately specified linear programming models can portray the peasant farming situations, despite the limitations on data. Accordingly, the model has been applied to identify the economic factors which limit agricultural production in Africa.

Mukhebi (1987) conducted a study to analyse the main constraints which limit major agricultural production on a co-operative farm in Nakuru district, Kenya. The result suggested that land, April and September labour constrain the production of milk, maize and wheat activities respectively.

Nelson (1984) employed LP technique to study all typical farm types in the main smallholder areas of the eastern province of Kenya. The findings revealed that large areas were uncultivated

since labour could not operate on all available land. The study also showed that vegetables and bananas even at relatively low yield are very profitable provided that market facilities are made available to sell the products.

Ruigu (1978) carried out a research to determine the effect of resource reorganization and also to evaluate the supply response of smallholder milk production in the central province of Kenya. The result indicated that optimal reallocation of resources under existing technologies and prices will increase farm income. Supply of milk was more responsive to operating capital than to increased milk prices.

Aring (1977) identified the farming techniques that give the maximum expected total farm income for small-scale farmers in Makueni location, Machakos district, Kenya. His findings included that ex-cultivation method gives the highest expected net return.

It was possible to increase farm income by improving tea and milk production, as the research findings of Ogwell and Clayton (1978) have revealed. The objective was to formulate a regional planning model for agricultural development in Nyeri district, Kenya. They imposed minimum subsistence requirements in the model taking into account risk and uncertainties. The optimal plan showed that surplus of potato was available for sale but other food crops such as maize and beans remained at a subsistence level of production.

The profitability of agricultural production and labour utilisation by smallholders in Hausa region, northern Nigeria was analysed by Norman (1973). Reallocating existing scarce resources and increasing prices of agricultural output will enable farmers to maximise their farm income.

The combinations of enterprises which bring maximum returns to farmers were investigated by Oluyide and Oluwude (1972). The study was conducted in the Western State of Nigeria. The finding indicated that arable farming with livestock enterprise is more profitable than tree crop farming.

Empirical Results and Discussion

I. Optimal Farm Plan.

Model 1. (Small farm)

The optimal farm plan does not include milk from crossbreed cows since they do not give adequate return to land at an average yield of 1,010 litres of milk compared to alternative enterprises.4 The main cash earning products are milk from grade cows, coffee, maize, beans and banana. The maximum gross margin obtained from the sales of these crops amounted to Kenyan Shilling (Ksh.) 4,310.9, and the share of milk in total farm income accounted for 29.2 percent. The total land area available for cultivation 2.04 hectares (ha.), and most of it is used to produce food crops and milk for household subsistence and sales (Table 1).

Land constrains the production of milk and food crops such as coffee, maize, beans and banana. As farmers shift from rearing crossbreed cows to keeping grade cows, the size of pasture land required for stocking such breeds increases simultaneously.6

Marginal value product (MVP) of land is Ksh 1,254.3 (table 1). The price of one hectare of land in the district is Ksh. 6,000, and the market rate of interest is 12 percent. The attractive rate of return provides incentives to invest in land, provided that credit facilities are made available to farmers.

Model 2. (Medium farm)

On medium farms, the most profitable enterprises are food crops and milk from grade and cross breed cows. The total farm income obtained from the sales of these enterprises amounted to Ksh. 8,861.6 and milk accounted for 72.5 percent of the total farm income. The prevailing condition did not allow the utilisation of all the 5.9 hectares of land available for use (table 1)

Working capital limits the production of milk and other enterprises. The marginal value product of working capital suggests that it is profitable to expand milk production since the expected rate of return is favourable compared to the market rate of interest (0.12 per annum).

As the number of dairy cattle increases, operating capital becomes a constraint. This confirms the high cost involved in maintaining and purchasing additional grade cows.7

Model 3 (Large farm)

Table 1 shows that crossbreed cows do not enter the optimal plan. They do not give adequate return to land or labour at an average yield of 993 litres per cow per year relative to alternative enterprises. The main cash earning enterprises are milk from grade cows, coffee and maize. The tota income obtained from the sales of these enterprises amounted to Ksh. 15,395, and milk accounted for 9[illegible] percent of the total farm income. The total land area available for cultivation is 7.98 hectares and most of it is utilized in producing food crops and dairying.

The factor of production that constrains the production of milk and other competing food crops is land (table 1). With the existing shortage of land, it is economic to keep eight grade cows at the current yield of 1,305 litres of milk per cow per annum. However, the annual yield of a grade cow is below its genetic potential due to lack of improved methods of feeding and husbandry.

Table 1

Optimal enterprise combination and marginal value product of limiting resources on small, medium and large farms (optimal farm plan)

Enterprise	Unit	Value of the plan			Marginal value product (Sh.)		
		Small	Medium	Large	Small	Medium	Large
Gross margin	Sh.	3,310.90	8,861.60	15,395.00	--	--	--
Land used	Ha.	2.04	3.48	7.98	--	--	--
Grade cow	Cow	1	3	8	--	--	--
Crossbreed cow	Cow	--	1	--	--	--	--
Coffee	Ha.	0.26	--	0.21	--	--	--
Maize	Ha.	0.58	0.33	0.10	--	--	--
Beans	Ha.	0.69	1.30	0.12	--	--	--
Banana	Ha.	0.15	0.15	--	--	--	--
Potato	Ha.	0.03	0.04	0.03	--	--	--
Cabbage	Ha.	0.10	--	--	--	--	--
Sunflower	Ha.	--	--	--	--	--	--
Resource							
Land	Ha.	--	--	--	1,254.30	--	2,813.00
Operating Capital	Sh.	--	--	--	0.10	4.15	0.10
Labour	Mhrs	--	--	--	--	--	--

Sh. - Shilling

Ha. - Hectares

Mhrs. - Manhours

Source - Computer print out

II Parametric Programming.

Land is the major constraint to produce milk and other food crops on small (2.04 hectares) and large farms (7.98 hectares). To determine the effect of change in land area on the optimal enterprise combinations, land input is increased successively by 0.25 and 0.50 hectares on small and large farms respectively, holding labour supply and operating capital constant. This variation is repeated until further increase in land size has no effect on the gross margin.

On small farms, land area is increased to 2.29 hectares, and the gross margin amounted to Ksh. 7,612. This showed an increase of 7.1 percent compared to the gross margin of the original farm plan. A further increase in land area amounted to Ksh. 3,852 showing an increase of 16.3 percent (Table 2). The increase in land area has scarcely any effect on the competitiveness of dairying versus other food crops. The same number of grade cows appeared in each optimal solution, the pattern of milk production remains virtually unaltered. This suggests that it is not economic to keep more than one grade cow for milk production at the current yield per cow per year, no matter how the constraining factor is varied. Holding labour supply and operating capital constant, increasing land area alone makes operating capital the limiting factor of production. This constrains the production of other enterprises (table 2).

On large farms, land is increased successively by 0.50 hectares holding labour supply and capital constant. Gross margin amounted to Ksh. 16,306, Ksh. 16,922 and Ksh. 17,303 on 8.48, 8.98 and 9.48 hectares of land respectively. The trend of the parametric variation in land area shows, as the constraint is relaxed, operating capital becomes a constraint and it limits the expansion of other food crops. The same number of grade cows appeared in each optimal solution, but as the size of the land is further relaxed, crossbreed cows appeared in the plan, and milk production increases (table 2).

On medium farms, the major constraining factor of production is operating capital. Capital is increased successively by Ksh. 500 and the gross margin amounted to Ksh. 15,408 and Ksh. 10,484. This showed an increase of 17.5 percent and 18.5 percent compared to the original farm plan (table 3). The result of the parametric programming suggests, as operating capital is made available, dairying becomes more competitive relative to other food crops. The pattern of milk production changes and the farm income increases. however, as land area is held constant and capital is varied, land becomes the limiting factor of production. Consequently, land constrains the expansion of food crops such as beans and maize.

ble 2

Summary of linear programming result,

land parametorised (Small and large farms)

	Small Farm			Large farm			
oss margin	3,310.00	3,612.00	3,852.00	15,395.00	16,306.00	16,922.00	17,303.00
nd used	2.04	2.29	2.54	7.98	8.48	8.98	9.48
erating capital	1,637.00	1,637.00	1,637.00	5,114.00	5,114.00	5,114.00	5,114.00
OPS/COWS							
ade cow	1	1	1	8	8	8	8
ossbreed cow	--	--	--	--	--	--	1
offee	0.26	0.13	0.01	0.21	0.17	--	--
ize	0.58	0.57	0.55	0.10	0.25	0.41	0.26
ean	0.67	1.09	1.44	0.12	0.51	1.02	0.85
anana	0.15	0.15	0.15	--	--	--	--
tato	0.03	0.03	0.03	0.03	0.03	0.03	0.03
abbage	0.10	0.10	0.10	--	--	--	--
unflower	--	--	--	--	--	--	
NSTRAINT							
and	1,254.00	1,109.60	--	2,613.00	1,394.00	1,038.90	--
erating Capital	0.10	0.10	0.10	0.10	0.10	0.10	2.69
bour - February	--	--	--	--	3.50	2.50	--
ell milk	1,354.00	1,354.00	1,354.00	15,442.00	15,442.00	15,442.00	16,4[illegible].00
ell coffee	550.00	271.00	29.00	443.30	355.55	--	--
ell beans	697.50	1,176.20	1,591.10	--	474.00	1,083.50	8[illegible].50

ource - Computer print out

Table 3

Summary of linear programming result,
operating capital parametrised (medium farm)

Gross margin	8,861.60	10,408.00	10,484.00
Land used	3.48	3.88	3.90
Operating capital	3,703.00	4,203.00	4,703.00
	--	+ 500	+ 500
CROPS/COWS			
Grade cow (Milk)	3	4	4
Crossbreed cow (Milk)	1	--	--
Coffee	--	--	--
Maize	0.33	0.58	0.60
Beans	1.30	1.39	1.39
Banana	0.15	0.15	0.15
Potato	0.04	0.04	0.04
Sunflower	--	--	--
[illegible]			
Land	--	--	1,038.90
Operating Capital	4.15	2.70	0.10
Labour	--	--	--
Sell milk	6,760.00	7,756.00	7,756.00
Sell maize	66.00	1,130.70	1,405.00
Sell beans	1,664.00	1,480.50	1,480.50
Sell banana	5.60	5.60	5.60

Source = Computer print out

Conclusion

The result of the study has revealed that land limits the production of milk and other food crops, on small and large farms. On medium farms, operating capital is a constraint to produce milk and other enterprises. With the existing shortage of land and working capital, farm income can be maximised by producing milk from grade and crossbreed cows, and food crops such as coffee, maize, beans, banana and potato. The gross margin obtained from the sales of these entreprises amounted to Ksh. 3,310.9, Ksh. 8,861.6, and Ksh. 15,395, and milk accounted for 25.6 percent, 74.5 percent and 95.6 percent of the total farm income respectively. The level of milk output can be maintained by keeping one, three and eight grade cows on small, medium and large farms respectively. The prevailing rate of interest is far below the marginal values of the limiting resources. Hence, the attractive rate of return provides incentives to increase milk production.

The trend of the parametric programming result has shown, on small farms, dairying is less competitive compared to other food crops. The pattern of milk production remains unchanged, and the same number of grade cows appears in each solution. Hence, it is not recommended to keep more than one grade cow at the current yield per cow per annum..

On large farms, as land area increases, dairying becomes competitive relative to alternative enterprises, and it is economic to keep eight grade and one crossbreed cows. Similarly, as the constraining factor (operating capital) is relaxed, milk production increases on medium farms. It is recommended that four grade cows should be kept to maintain the current level of milk output.

Dairy industry development is feasible in the study area. But farmers should be given incentives such as credit facilities to enable them to purchase additional farm inputs. Thus, milk production will be intensified by keeping grade cows and improving the methods of feeding. With intensification, labour and capital will be effectively utilised. Financial institutions such as commercial banks and cooperative societies should make available short-term credit needed to finance regular expenditures for buying concentrate, dipping and other veterinary expenses. Long term credit needed to finance capital investments such as stables, water supplies and to purchase grade cattle should also be given due consideration..

Footnotes

1. All farms with less than 20 hectares farmland are considered small-scale according to the definition of small-scale farms as applied by the Bureau of Statistics in Kenya.
2. Zebu is a small short horn and is the main local breed. Crossbreed is the first generation of zebu and grade cattle. Grade cattle are Freisian, Ayrshire, Guernsey and Jersey.
3. An optimal farm plan has been defined as one which under physical, technical and resource conditions, shows what enterprise to undertake and how much land to allocate to each activity so that the net farm returns are maximised.
4. Recorded milk yield per lactation of a grade cow on small, medium and large farms are 1,244, 1,372 and 1,305 litres respectively. The yields of a crossbreed cow are 1,020 litres on small farms, 1,067 on medium farms and 993 litres on large farms. Alternative enterprises are coffee, maize, beans, banana, potato, cabbage and sunflower.
5. Exchange rate (average), 1991.
   1 US dollar = 26 Kenyan Shillings.
6. Pasture land required for stocking per cow:
   a) Grade cow (on small farm = 0.23 hectares,
      on medium farm = 0.43 hectares,
      on large farm = 0.94 hectares).
   b) Crossbreed cow (on small farm = 0.19 hectares,
      on medium farm = 0.37 hectares,
      on large farm = 0.82 hectares).
7. Purchasing price of a:
   a) Grade cow Ksh. 5,000 b) Crossbreed cow 4,200

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