THE EFFECTS OF ALTERNATIVE BREED TECHNOLOGIES AND RESOURCE ALLOCATION ON THE STRUCTURE OF BRAZILIAN MILK PRODUCTION

By

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MILK PRODUCTION

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CHAPTER I

INTRODUCTION

Scope

Brazil's dairy industry is facing a deep transformation caused by market deregulation, an opening economy with increased regional integration, and a market – oriented macroeconomic plan, the Real Plan. Market deregulation changed the locus of price formation from the table of the government to a market environment. Concurrent, opening the economy increased competition, bringing new and cheaper products mainly from MERCOSUL countries. This has raised concerns about production viability and profits, especially because Brazilian milk producers are thought to have a low productivity.

In order to adjust to the new environment farmers can change the current breed technologies and/or make better resource allocation. There are six different breed technologies (Brown Swiss, CrossHZ, Gir, Guzerat, Holstein and Jersey). The optimal breed selection is best determined jointly with different resource allocations (amount of land, herd size, facilities and capital) that can be used by milk farmers. As producers and research groups recognize the best allocation and choice, they should be able to achieve efficiency and profitability.

The purpose of this project is to evaluate the economic farmers choices including alternative breed technologies and better resource allocation. To accomplish this goal the research will develop a flexible bioeconomic model. This model will be used to identify the specific causes of inefficiency and to suggest better technologies and resource allocation under expected economic conditions. In addition, this model will be calibrated based upon the conditions similar to those faced by typical Brazilian producers. specifically:

General Objective

To determine the economic consequences of alternative breed technologies and better resource allocation on productivity and profitability of Brazilian milk production.

Specific Objectives

(i) To create a flexible model to evaluate a complete milk production system;

(ii) To determine profitability of current milk production systems and identify specific causes of inefficiency;

(iii) To determine the economic consequences of alternative milk production systems in the Brazilian environment.

The remainder of this chapter describes the structure of Brazilian milk production. In addition, it documents the increases in trade, the decreases in milk prices and profits received by dairy producers, and the low productivity growth in the Brazilian diary industry. These provide the motivation for the work described in succeeding chapters.

Background

Although milk producers face decreasing profits and production is inefficient, Brazilian milk production has been growing quickly. This apparent contradiction is only a small sign of the big change in progress in the dairy industry in Brazil.

World production of fresh whole milk was greater than 480 million metric tons in 1999 (FAO statistic – 2000). Brazil is the sixth largest producer with 22.5 million metric tons accounting for 4.7% of world production. World production grew at 0.33% per year from 1985 to 1997. In the same period, Brazilian production grew 3.19%, almost 10 times more than world production growth. Nevertheless, even with this superior performance, Brazil remains a net dairy importer.

Brazil imported an average of 12,735 metric tons of butter per year from 1993 to 1998, corresponding to 18.96% of the butter produced (Table 1). The amount of milk imported corresponds to 10% of the milk produced from 1993 to 1998. Most of these imports were in the forms of cheese. The amount of imported cheese during the considered period corresponds to 98.26% of the total amount of cheese produced in Brazil, implying that half of the Brazilian cheese market has been supplied by imports since the Real Plan started. The biggest change occurred between 1993 and 1994, where production decreased by 44.88% while imports increased 323.4%. This change occurred mainly because of the open market provided by the Real Plan.

Waste is also an important aspect. Brazil was the third largest waster in the world, behind only Somalia and Pakistan. Brazil wasted 932.5 thousand metric tons of milk on average per year, exclusive of butter, from 1993 to 1998. This amount corresponds to

5.02% of the total milk produced and corresponds to 49.3%[1] of the average amount imported in the same period. The waste should be a matter of future research to explain why waste primarily arises.

TABLE 1

BRAZILIAN DAIRY INDUSTRY PERFORMANCE
(1993 – 1998)

		Year						
Product	Activity	1993	1994	1995	1996	1997	1998	Average
Butter	Production	68,000	70,000	65,000	70,000	72,000	70,000	67,167
	Imports	8,855	13,735	20,874	12,257	6,995	13,693	12,735
	Exports	3	-	3	-	1,994	86	348
Cheese	Production	60,150	33,150	22,800	33,150	33,500	38,500	36,875
	Imports	8,047	34,071	89,345	33,866	28,513	23,556	36,233
	Exports	317	215	954	462	391	718	510
Milk	Production [1]	16,218.2	16,415.3	17,126.1	19,230.4	20,741.0	21,771.0	18,583.7
	Imports[1]	684,520	1,196.7	3,531.9	2,281.9	1,712.2	1,940.8	1,891.5
	Exports	138.91	8.35	15.74	56.86	15.18	17.89	42.15
Total	Waste[1]	811.3	821.3	859.1	965.9	1,042.7	1,094.9	932.54
	Supply/cap[2]	94.8	98.5	116.3	118.4	122.1	128.0	113.0

Source FAO (2000). Units in metric tons; (1) thousand of metric tons; (2) kg/cap/year

Brazil increased supply per capita over the period 1993 to 1998, reaching 128 liters/cap/year, which corresponds to a 4.32% growth rate over the period considered. However, this growth has been not enough to supply the Brazilian market.

Brazil is the largest market in South America and is a net importer. The imports grew fast after the implementation of the Real Plan in 1993 and trade deregulation, including MERCOSUL. The Brazilian Central Bank[2] reports more exports to and imports

[1] Data calculated by the author using FAO information.
[2] Brazilian Central Bank Reporter (1999)

from MERCOSUL countries since integration began. For Brazil, exports of all products grew 50% while imports grew 208% from 1992 to 1995.

TABLE 2

MERCOSUL DAIRY TRADE
(1993 – 1998)

	Imports		Export		
	Quantity	Value	Quantity	Value	Trade Balance
Country	Metric Tons	1000 US$	Metric Tons	1000 US$	1000 US$
Argentina	152,782	52,961	612,994	216,561	163,600
Bolivia	53,526	15,881	2,530	739	-15,142
Brazil	1,578,578	432,228	33,072	11,032	- 421,196
Chile	194,604	54,360	69,298	23,816	-30,544
Paraguay	42,486	16,668	31	13	-16,655
Uruguay	4,978	1,969	348,034	126,832	124,863

Source: FAO (2000) in milk equivalent.

Among MERCOSUL countries, Argentina and Uruguay are the most important exporters of dairy products, with 0.8% and 0.47% of world exports, respectively (Table 2). They have a lower production cost because of the lower input pasture based milk production system. Therefore they have a comparative advantage provided by their environments and can supply to the Brazilian market at competitive prices.

In addition to trade, an important issue affecting Brazilian milk producers is the production environment. This can be seen most effectively by contrasting the Brazilian environment with those of others countries.

Baas et al. (1998) identify four dairy production systems worldwide: (i) grazing system in Oceania, UK, Ireland and Argentina, (ii) silage system on the European continent and parts of the US and Canada, (iii) subtropical system in southwest America and northern Mexico and, (iv) tropical system in southern Mexico, Brazil and India. They suggest that a dairy farming system is selected considering complex factors such as herd size, feed availability, housing, milk yield and cow productivity. These variables are influenced by regional climate, forage bases, farm structures and size, dairy policy and market conditions. The farmers' choices can also be influenced by the price of labor, capital and cereals and, of course, by the milk price received from processing firms.

Baas et al. suggest that efficient producers in the Southern Hemisphere, such as Australia, New Zealand and Argentina, are able to use low cost, seasonally-based pasture feeding techniques. In many Northern Hemisphere countries the climate is such that herds have to be sheltered indoors for extended periods and output can only be maintained by using considerable supplementary feeding, increasing the average milk cost.

The Baas classification provides an idea of the system most frequently adopted in different areas around the world. In Brazil, it is possible to find all four systems in the same climate-pattern area, but it is apparent that the climate and other complex factors help determine the 'face' of a dairy farming system. One of the important characteristics in this classification is the productivity of the systems. Table 3 indicates that the tropical system has the lowest productivity per cow, with one-ninth the productivity of the subtropical and silage system, and one sixth that of the grazing system adopted in New Zealand and Argentina. This issue will be discussed later.

TABLE 3

DAIRY FARMING SYSTEM WORLDWIDE

Variables	Grazing System New Zealand, Australia, Ireland, UK, Argentine	Silage System European Continent, USA north east, Canada	Subtropical System USA south west, Mexico North	Tropical System Brazil, India, Mexico South
Climate	Temperate	Temperate	Subtropical dry	Tropical, humid
Herd size	50-500	10-250[1]	300-2,000	2-100
Milk yield[2]	4,000-6,000	6,000-9,000	9,000-10,000	1,000-2,000
Forage feeding	Own production Grazing Concentrates	Own production Grass and corn silage Concentrates	Purchase feed Grass, corn silage/ hay Concentrates	Own production Green chop Concentrates
Housing	None/very few	Yes	Sun roof	None
weather Risk	High	Medium	Low	High
Seasonally pattern	High	Medium	Low	High[4]
Ownership structure	Family farming income oriented	Family farming income oriented[3]	Commercial farming assets return	Family farming oriented to self-sufficiency
Costs (per kg milk)	Very low- low	Medium- high	Low	Low[4]

Source Baas et al. (Rabobank, 1998). (1) Herd size: Eastern Europe and East Germany 20-2000 cow/ farm. (2) Kg/cow/year. (3) Except cooperative type of farming in Eastern Europe. (4) Completed by the author.

Classification helps to understand and compare systems and there are several ways to classify production systems. Minas Gerais State Diagnostic[3] (MGD), for example, classifies the producers by the level of their milk production per day using categories of 50, 51-250, and greater than 250 liters/day. Gomes (1999) uses cow breeds to characterize the milk production system in Brazil, with results similar to the MGD results. He thinks that the breed characteristics and technical parameters determine feeds, housing and facilities required for each system. Gomes also mentions other discriminative variables such as extensive or intensive production, family labor or hired

[3] Minas Gerais State Diagnostic Report (SEBRAE_- MG 1996)

labor, subsistence or commercial farms, grazing or sheltered as possible variables to be used to characterize the farming systems.

Gomes characterized Brazilian systems in three different levels: (i) Zebu system with either pure Zebu or crossbreed Holstein-Zebu with Zebu dominance; (ii) crossbreed system with blood level between ½ to 7/8 Holstein-Zebu; (iii) European breeds system. Gomes did not differentiate in the European breeds among, for example, Holstein, Jersey or Brown Swiss.

TABLE 4

DAIRY FARMING SYSTEM IN BRAZIL

Variables	Zebu System	Crossbreed System	European breed System
Required technical knowledge	Low	Medium	High
Feed regime	Grazing, mineral supplement	Grazing, green chop, concentrate	Grazing , corn silage, concentrates
Productivity	Low Low variability	Low-Medium, High variability	Medium-High, low variability
Land used	High	High - Medium	Medium - Low
Capital used	Low	Medium	High
Risk	Very low	Low	Medium-High
Farm size	Small	Small-Medium	Medium-big
Production cost	Very Low	Low	Medium

The author constructed the table based in Gomes (1999).

The Crossbreed System is predominant, corresponding to 80% of the systems used to produce milk in Brazil. The main reason for using this system is the low risk level (Gomes 1999, Gomes A. 1999, Brandao 1999, Alves e Assis 1998). Brandao (1999) thinks that farmers have been using crossbreed because of their dual-purpose characteristics, trading off between milk and meat production. When the milk price is low, the beef price is expected to be high because of the negative relationship between them in Brazilian market. Therefore, farmers increase the slaughter of milk cows when milk prices decrease, increasing the cash inflow from beef production; they do the opposite when the milk price is high. Gomes (1999) suggested that farmers prefer a low – investment cow because in the case of animal death the loss will be lower since its price is low.

The system productivity impacts the productivity of the dairy industry as a whole and determines the way of the milk production grows. The Brazilian system is based on low quality pasture, high amount of land, and cows with low productivity. These characteristics impose a development model where herd growth explains more of the increase in production than does productivity growth. In other words, the expansion of production is based more on the increase in the number of cows (extensive growth) than on productivity (intensive growth). Gomes (1999) suggested that the Zebu system has an inelastic supply curve, due to low productivity per cow. Consequently, its response to milk price changes is small and ineffective.

Milk production growth depends on increases in herd size and/or increases in cow productivity. Table 5 shows that Brazilian milk production growth is based more on herd size expansion than an increased productivity per cow. Productivity growth explains only 40.61% of the milk production growth from 1990 to 1995, while herd size expansion explains 59.39%. The productivity of the milk production system is very low compared to the international level, and it has been growing at a very small rate. Milk production grew 3.59%[4] per year from 1960 to 1999 with herd expansion accounting for most of the growth.

TABLE 5

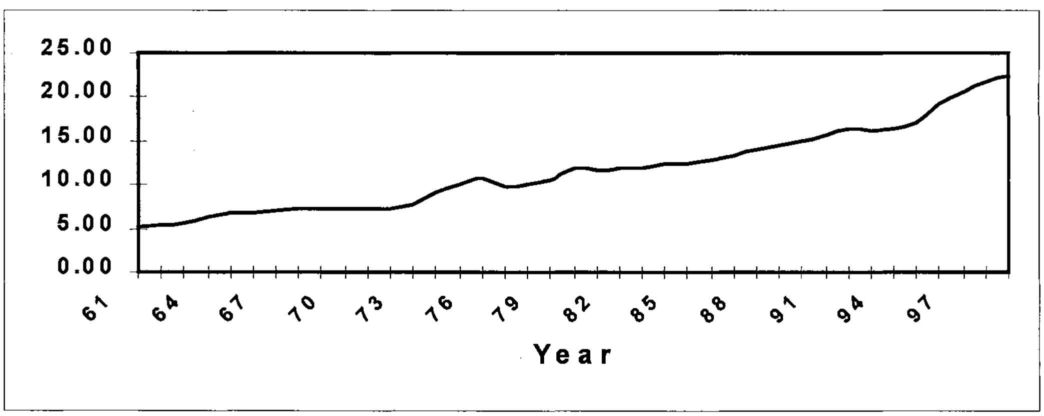
PRODUCTION, PRODUCTIVITY AND HERD SIZE GROWTH (1990[1] – 1995)

Year	Production Growth (%)	Productivity Growth (%)	Herd Growth[2] (%)
1991	4.11	-0.54	4.65
1992	4.67	2.06	2.61
1993	-1.22	1.01	-2.23
1994	1.24	1.01	0.23
1995	4.38	1.79	2.59
Average	2.61	1.06	1.55

Source: (IBGE). (1) Base year; (2) Production growth minus productivity growth.

FIGURE 1

BRAZILIAN MILK PRODUCTION GROWTH (1960 – 1999)



Source: FAO (2000) – production in billion liters.

[4] Calculated using FAO (2000) information

Figure 1 shows production growing systematically. In addition, Figure 1 shows that production grew with different intensity from period to period. The slope of the milk production growth line represents this different growth pattern. Dividing the period considered (1960 - 1999) into decades, we makes differences in pattern growth more apparent.

FIGURE 2

MILK PRODUCTION (1961 – 1969)

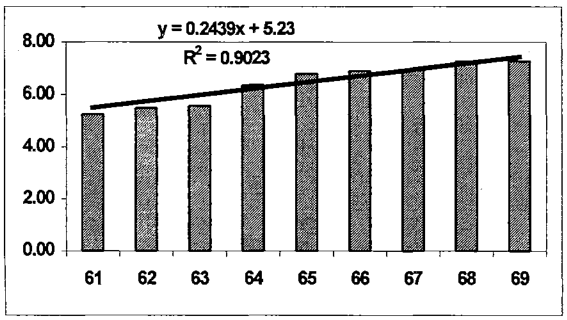
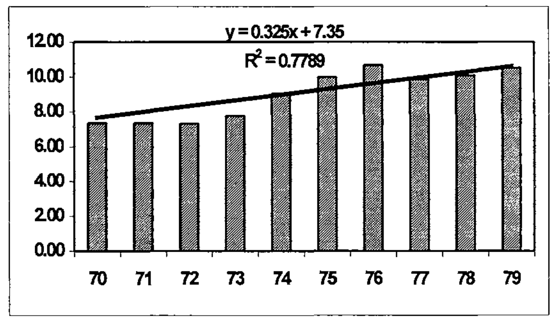


FIGURE 3

MILK PRODUCTION (1970 – 1979)



Source: FAO (2000) – production in millions metric tons.

FIGURE 4

MILK PRODUCTION (1980 – 1989)

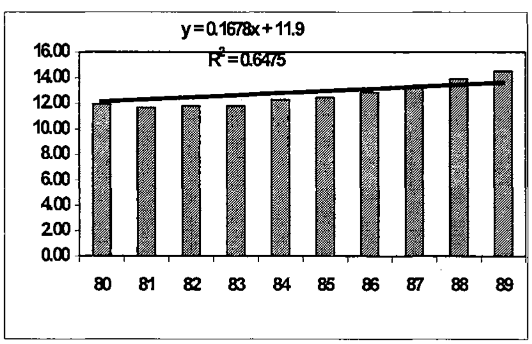
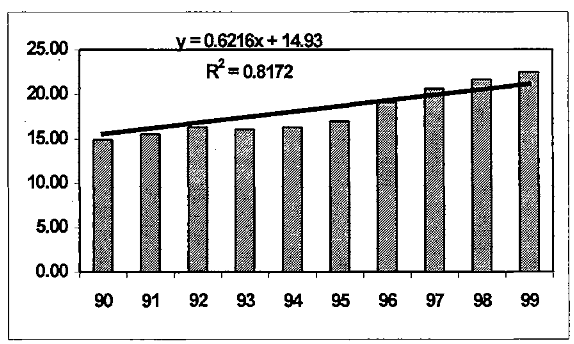


FIGURE 5

MILK PRODUCTION (1990 – 1999)



Source: FAO (2000) – production in millions of metric tons.

The intercept for each trend line is equal to the value of the production in the first year of the period considered, letting the slope of trend lines show the speed of the growth process. The trend lines fit the data reasonably well, with the lowest R^2 equal to 0.65. The decade 1960 – 1969 was used as a base to construct a slope index (Table 6).

TABLE 6

MILK PRODUCTION GROWTH SLOPE INDEX
(1960 – 1990)

Decade	Slope of the Trend line	Slope Index
60*	244,291	100
70	324,519	132.84
80	168,388	68.93
90	621,104	254.25
Average	339,576	139.00

* Base year. Data calculated using FAO (2000) Brazilian production records.

The slope represents the growth in milk production per year in the decade considered. The slope index, using the 1960s as a base, shows consequently that in the 1970s milk production grew 32.84 % more per year than the pattern showed in the 1960s. In the 1990s, it grew 2.5 times faster than in the 1960s. The strength of the 1990s was enough to overcome bad years such as occurred during the 1980s. The average production growth from the 1970s through the 1990s was 39% bigger than in the 1960s.

The milk production structure reported in the Brazilian Agricultural Census[5] (BAC) shows that 65% of the milk production came from cattle farms, 21.3% from mixed cattle and crop farms, and 11.7% from farms where crops were the principal operation. In addition, 75% of the milk produced came from specialized herds, where the main purpose of the cows was milk production. Herd specialization has been growing since 1980 when the BAC reported that 65% of the milk produced came from specialized herds.

The ownership structure is family farming and the milk production is concentrated in farms with 500 hectares or less; 92.83% of Brazilian milk production comes from farms with this amount of farmland or less.

Farmers with 50 hectares is the most important group, accounting for 22.75% of the milk production in Brazil (Table 7). Brandao (1999) indicated that farms with less than 20 hectares account for 21.31% of the milk produced.

Farms with 20 to 100 hectares, accounted for 53%, and farms with 20 to 500 hectares accounted for 83% of the total milk produced.

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[5] Agricultural Census (IBGE 1995 – 1996)

TABLE 7

MILK PRODUCTION BY FARMLAND AREA
(1996)

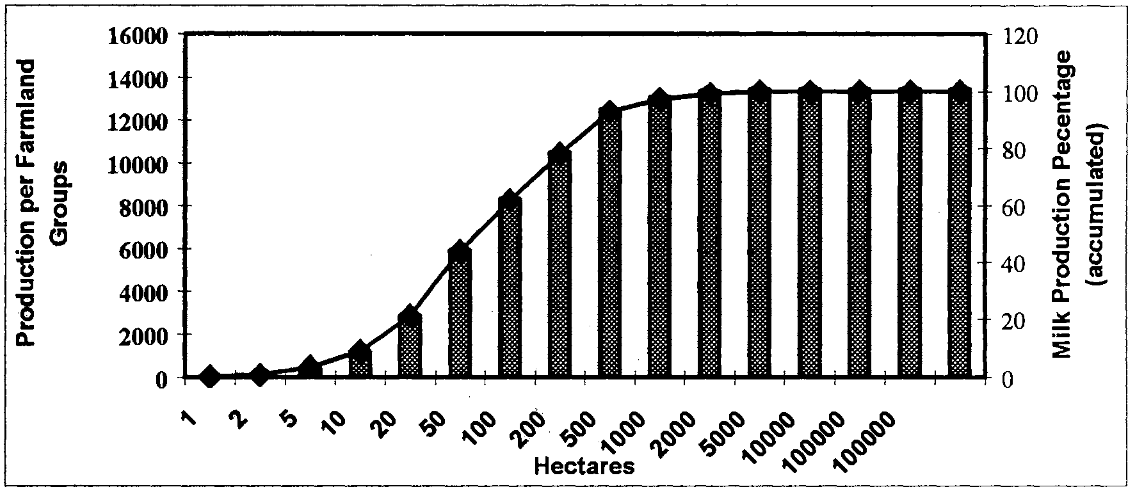
Farm size Hectares	Milk Production (Millions liters)	Accumulated Milk Production	Percentage of Production	Accumulated Percentage
1	46.30	46.30	0.34	0.34
2	68.81	115.11	0.51	0.85
5	350.36	465.46	2.60	3.46
10	733.43	1,198.89	5.45	8.90
20	1,670.55	2,869.44	12.41	21.31
50	3,062.76	5,932.20	22.75	44.06
100	2,396.30	8,328.50	17.80	61.86
200	2,189.77	10,518.28	16.26	78.13
500	1,979.62	12,497.90	14.70	92.83
1000	613.94	13,111.84	4.56	97.39
2000	257.58	13,369.42	1.91	99.30
5000	81.27	13,450.69	0.60	99.91
10000	7.31	13,458.01	0.05	99.96
100000	2.34	13,460.35	0.02	99.98
100000 +	0.01	13,460.36	0.00	99.98
Not declared	2.78	13,463.14	0.02	100.00

Source: IBGE Agricultural Census 1995-1996

To analyze productivity of milk production by farm category, cow productivity is used as a proxy variable. Gomes (1999) suggested this procedure. First, the proportion of total cows that were milked was calculated. This proportion was calculated by dividing the total milked cows in 1996 by total cows in the same year. The result was equal to 0.1063, meaning that out of 100 animals, 10.6 were milked. This ratio, assumed to be the same for all farm groups, was multiplied by the herd size in each group to determine the number of milked cows per group. Cow productivity is equal to the number of milk produced divided by the amount of milked cows in each group.

FIGURE 6

ACCUMULATED MILK PRODUCTION BY FARMLAND AREA
(1995 – 1996)



Source: IBGE Agricultural Census (1995 – 1996) (1) Milk production in millions of liters

The farmland groups that achieved productivity greater than 2,000 liters/cow/year were those with 10, 20, and 50 hectares per farm. The most productive of these is the group with 20 hectares per farm, with a productivity of 2,366 liters/cow/year.

The productivity of the groups with 5 and 10 hectares is 1,727.91 and 2,110.84 liters/cow/year respectively. Their productivity is greater than that of the 100 and 200 hectare groups, perhaps because they are more specialized.

Table 8 and Figure 7 show that the group with farm size of 100 hectares is the largest group, with 872,217 farmers. They also show that big producers in Brazil normally have other activities than milk production - typically beef production – with low productivity. Therefore, most of the milk produced in Brazil is produced on farms with less than 200 hectares of farmland.

TABLE 8

MILK PRODUCTION AND PRODUCTIVITY PER FARMLAND
(1996)

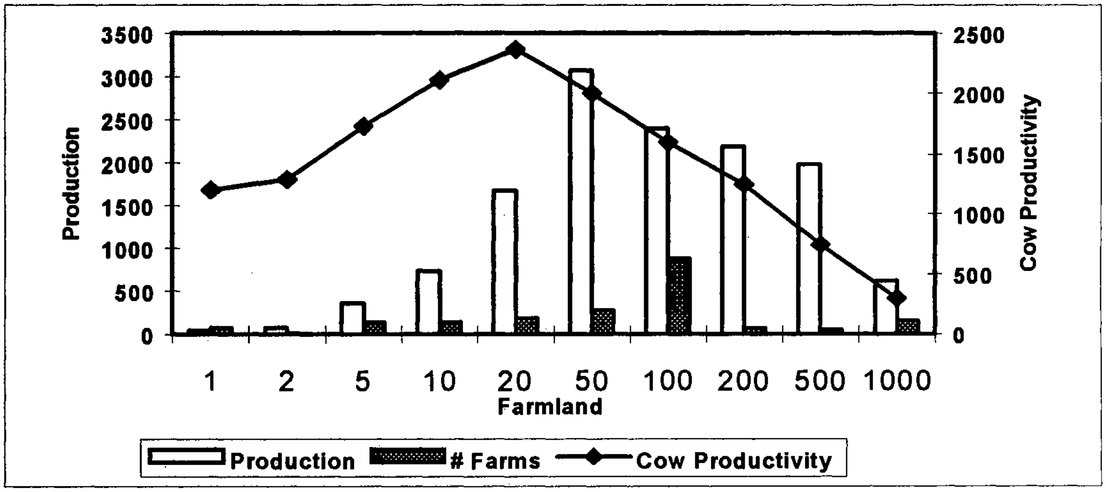
Farm Size Hectares	Milk Production (Millions liters)	Total Farms	Cow Productivity Liters/cow/year
1	46.30	70,306	1,201.83
2	68.81	5,999	1,288.25
5	350.36	141,938	1,727.91
10	733.43	140,496	2,110.84
20	1,670.55	185,686	2,366.52
50	3,062.76	274,483	2,005.34
100	2,396.30	872,217	1,595.78
200	2,189.77	66,382	1,247.90
500	1,979.62	50,245	742.06
1000	6,13.94	156,793	299.23

Source: IBGE Agricultural Census (1995 – 1996)

The agricultural census 1995 – 1996 reports the existence of 1,810,041 milk producers, 37% of all farmers in Brazil. The Census includes as a milk producer all producers who dedicate at least part of their activities to produce milk. These include both commercial and subsistence farms that have one cow to feed their family. Table 8 and Figure 7 included all cattle farms that report milk production in the Census. Gomes A. (1999), reporting estimation by Gomes (1999) and by Jank and Galan (1999) estimations, reported 1,182 thousand commercial producers, including producers working in the informal market.

FIGURE 7

MILK PRODUCTION, PRODUCTIVITY PER COW AND NUMBER OF FARMS (1995 – 1996)



Source: IBGE Agricultural Census (1995 – 1996) (1) Production in millions of liters; (2) cow productivity in liters/year; (3) farmland in hectares; (4) farms in thousands (see Table 8).

Farms working in the informal market do not pay tax, do not operate under government sanitary and hygienic official inspection, and do not appear in the official statistics. They sell products directly to consumers, normally crude milk and homemade cheese. The informal market dimension is unknown. There are several tentative measures to estimate this number but, in reality, it is very difficult task. Gomes (1999) estimated it in 1997 to be equal to 46%.

In addition, Gomes (1999) estimated that the informal market produced more than 8 billion liters in 1997. In 1991, the year of the market deregulation, the decline of the informal market stopped, and the informal market has been growing quickly again.

TABLE 9

ESTIMATION OF INFORMAL DAIRY MARKET

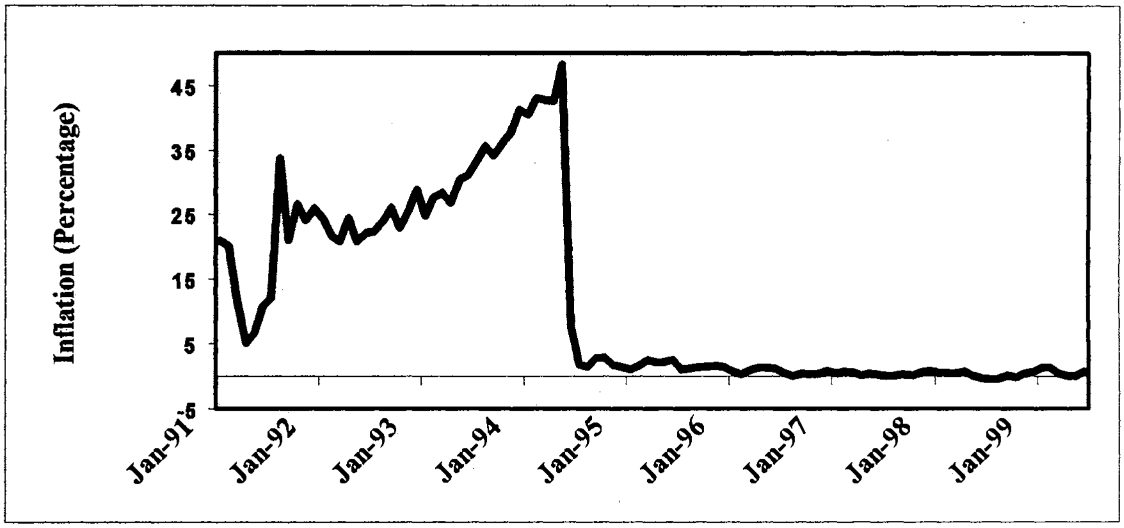
Year	Informal Market (Millions of liters)	Informal Market (%)
1985	4,012	27
1986	3,794	30
1987	2,960	23
1988	3,260	24
1989	2,960	18
1990	3,737	16
1991	4,666	31
1992	4,084	32
1993	6,445	41
1994	6,343	40
1995	6,612	39
1996	7,661	40
1997	8,946	46

Source: Data reproduced from Gomes (1999)

Brandao (1999) found that volatility and decreasing milk prices have had a negative impact on milk production. From 1991 to 1994, price volatility has increased and the milk price has decreased, as the informal market has increase. The volatility of prices, according to Brandao (1999), is the important factor in the milk production, because "...with less volatility farmers can conduct a long term planning with a more rational investment program." (p. 51). Actually the effects decreasing prices and increasing price volatility are reflected in the pattern of production growth (Figures 8 and 9).

FIGURE 8

INFLATION RATE
(1985 – 1999)



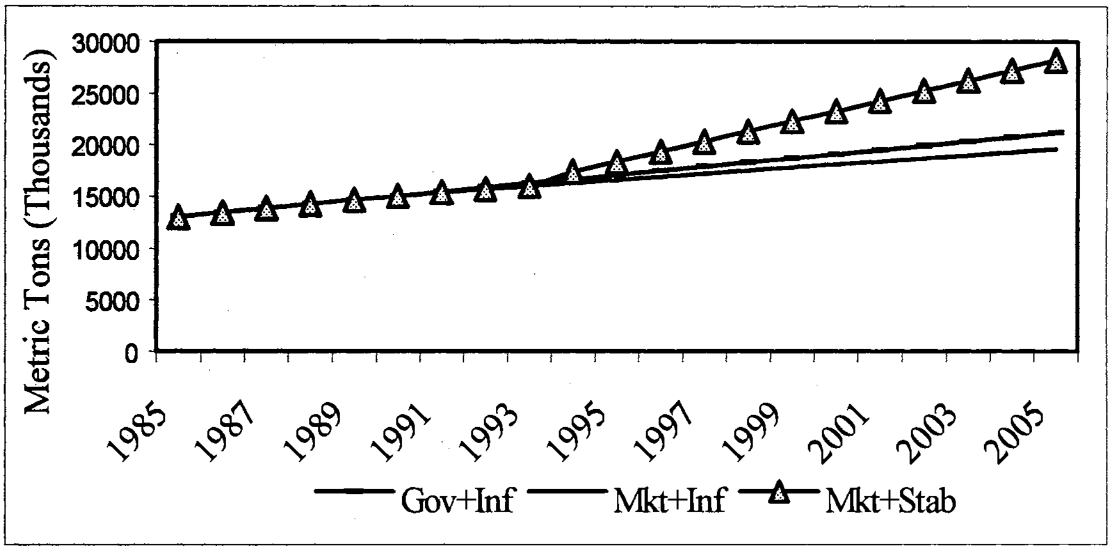
Source: INPC (monthly data) IBGE

To test the impact of the volatility and market deregulation on the production growth pattern a trend line function was constructed with information about quantity of milk produced. Three periods were considered: before the market deregulation, when the Government controlled the price and there was inflation (1985 – 1990); after the deregulation and inflation persisted (1991 – 1994); and after the economic stabilization (Real Plan) when the market regulated the prices and inflation was under control.

Figure 9 indicates that milk production growth is smallest when there is inflation and market – directed prices. The possible conclusion here is that government – controlled prices could be less bad than market – directed prices under high inflation. However, the best economic environment for milk production growth is when there exist market prices and a stable economy.

FIGURE 9

PROJECTED MILK PRODUCTION USING TREND LINE FUNCTION



Data calculated by the author using information of milk production (1985 – 1998) IBGE

Brandao (1999) concluded, and the previous analysis showed, that both decrease milk price and inflation have a negative impact on the milk production growth but that stabilization was the most important of these two factors.

Brandao (1999) showed that the decreases in milk price did not began with market deregulation. Using a real milk price index, he demonstrated that the milk price been decreasing since 1975. Therefore, the government milk price control was not effective to protect the milk producers or to stabilize milk price, since the price volatility was strong and the prices decreased during the milk price control period. This reality has good and bad news for milk farmers. The good news is that milk production can increase quickly under market control and stable economy. The bad news is that under market – directed prices, inflation must be controlled and milk price will adjust to the international level.

The decrease in price has been pressuring production margins, and reported milk production profit has been very low. Gomes (1998) estimated margins equal to US$0.017/liter in September 1998. IBGE data (1996) report production per farm equal to 810 liters/farm/month projecting an income equal to US$13.77 per month considering the margin suggested by Gomes. If only professional producers - understood as producers delivering milk to processing firms - are considered, the numbers change slightly. Gomes (1999) reported a daily average milk production, considering only farmers delivering milk to the biggest processing firms, equal to 80/liters/day or 2,400/liters/month. This average projects a monthly income equal to US$40.80. Now suppose that Gomes is wrong and the profit is bigger, say 2 or 3 times more. The projected profit is still very low, concluding that under the current margin the production system used cannot provide adequate return to fixed costs. Therefore, there exits a strong incentive to dairy farmers to change the milk production system or abandon the activity. The primary purpose of this work is to identify alternative solutions for dairy.

In brief, Brazil is the sixth largest milk producer in the world and a net dairy importer. More than one million farmers operate in Brazil producing 22 billion liters per year. The producers are small with average production less than 80 liters/day using a tropical system with crossbreed animal (Zebu-Holstein). Production has been growing faster than the demand and the main factor explaining production growth is the increase in herd size. The productivity per cow is less than 2,000 liters/cow/year and has been growing at a low rate. The relevant macroeconomic factors are the trade liberalization with regional market and growing imports, and dairy market deregulation so that prices are market – directed rather than government – controlled. The economic stabilization provided by the Real Plan appears to be the most important macroeconomic factor affecting the milk production growth pattern.

The milk farmers' major problems are the economic consequences of continuing declines in milk prices associated with low productivity. Therefore, the general objective of this work is evaluate the economic consequences of alternative breed technologies and better resource allocation for productivity and thus profitability of Brazilian milk producers.

CHAPTER II

LITERATURE REVIEW

Introduction

This literature review addresses two basic areas. First it identifies the most important variables for milk production, in the context of the production systems and outlines the effects of milk price decreases. Second, it reviews programming theory and the numerical optimization techniques used in this work.

Milk Production System

Milk production, like agricultural in general, is a biological process transforming inputs into output. Because the inputs are not free and the outputs have value, milk production is also an economic event. It constitutes a bio-economic system where several biological variables interact with each other and with economic variables, produce some marketable products.

The most important biological variable is the milk cow. It is the most important because cows are the 'milk processor', transforming feed inputs into milk. Farias (1997) suggested that the milk cow should be considered as a basic production unit in a milk production system. The specialized milk production cow is 'a milk production machine' with many differences from one selected to produce meat. Normally, milk cows have a calm temperament, and their period of milk production is longer, assuming they have adequate nutrition and an appropriate environment.

Among the inputs required to produce milk, feeds received by cows are the most important. They are the most important inputs because they provide the required nutrients to be transformed into milk and meat. Inadequate quality and amount of feed can stop milk production and increase risk of disease and death.

On the economic side of milk production, the most important factors are resource allocation and production cost. They determine the amount of investment and the profitability of the milk production system. They are of special interest in this study because producers have some degree of control over them.

The complex of cow-feed, available resources and production costs determine the system performance. Some studies in Brazil have pointed out the major problems currently found in Brazilian milk production. Gomes, S. (1999) and Brandao (1999) have both reported, among others, the following problems:

(i) High production cost.

(ii) Lack of information about alternative milk production systems.

(iii) Inadequate production scale.

(iv) Scarce and difficult credit and capital accessibility.

They emphatically argued that a large number of milk producers with small scale and lower quality, is one of the most important problems of the dairy industry in Brazil. They indicated that the major problems of production cost and scale are linked and play an important role in determining profitability.

Brandao and Gomes indicate the major problem without discussing the reasons. A focus of this research is to understand the economic reasons for the small scale production that is prevalent in Brazil and to predict changes in structure that might occur in response to changing external factors.

Gomes (1999) reported that productivity and profitability differences between big and small milk farmers continue to increase in Brazil. At first glance, it appears that he is suggesting a positive relation between size and profitability and size and productivity. Profitability is clearly linked to size when the production function exhibits increasing or constant returns to scale and there is no restriction on the amount of milk that the farm can sell.

However, the same is not valid concerning productivity. Productivity appears to be linked with resource allocation and technology without connection to production size. The production technology adopted determines the productivity of the resource by imposing a ratio among inputs and the transformation ratio between inputs and output.

Weersink and Tauer (1991) adopted the conventions of viewing productivity as milk production per cow and dairy farm size as number of dairy cows. They measured productivity using multivariate Granger-causality testes reporting that changes in productivity and changes in average herd size are linked or driven by price changes. Weersink and Tauer report results in accordance with Jesse (1987) who reported no relationship between milk production per cow (productivity) and farm size. However, Weersink and Tauer reported that these empirical results only partially support the view that productivity change has caused changes in the average herd size. One possible implication of this result is that increasing productivity may not increase the size of farms. They also reported that herd size could cause a change in technology. This report and Gomes (1999) express the same principle. Even if a larger herd size does not always imply greater productivity, the adoption of new and more productive technology may require investment that big farmers can afford but small ones cannot. If new and more productive technologies require large investment, the productivity gap between small and big farms may increase since small farms may not be able to afford the investment. Thus, the increase in productivity related to changing production technology might be indirectly related to herd size, as Gomes has suggested.

El-Osta and Johnson (1998), using data from farm cost and returns survey in a multivariate analysis framework, examined the variation in the net farm income of commercial farms in United States. They reported that size of operation, regardless of the location of the farm business, is an important determinant of farm profitability. They also found that, on a per-unit-of-returned-basis, factors most important in explaining the variation in net returns per hundredweight of milk sold were cow productivity, per cow forage production and costs of purchased feeds. These results are similar to those of Kaiser et al. (1994).

Tozer and Huffaker (1999) examined how the deregulation of the Australian dairy industry could affect the utilization of resources by milk producers and the profitability of dairy production. They modeled a pasture based bio-economic model searching for the interactions of pasture utilization and farm profitability. They reported that profitability of low-input dairy production (pasture based) is constrained by the feed supplied by pasture, and that the interactions between economic and biological processes are critical to farm profitability. They concluded that the representative Australian dairy farmer's best response to total deregulation and a milk price decrease is a highly productive pasture, and the use of hay as a feed. In addition, they suggested that when milk prices are high enough to justify the purchase of supplemental feeds, it should be done.

The work of Ramsden et al. (1999) supports the idea that milk price, feeding system and cow productivity determines farmer profitability. Using a linear programming model, they studied the impact of changes in milk price to milk-quota-leasing price ratios, nitrogen fertilizer and concentrate prices on the profitability of a technically efficient UK dairy farm. The results show that if the milk prices in UK go down there is a large financial incentive to reduce input levels and move to lower yielding cows as milk to milk-quota-leasing price ratio falls relative to prices for concentrates and nitrogen fertilizer.

McCall and Clark (1999) used a linear programming model to compare factors that optimize milk production in the Northeastern United States and New Zealand grazing systems. The model compares the optimum characteristics of each system over a range of milk prices. They reported that as milk price decreased the pasture area increased and some potential grain area was replaced by forage crop as a cheaper feed alternative. However, when the grain price is lower relative to the milk price, using more grain can support higher daily cow production. Pasture deficits are covered by supplementary feed, and a long lactation provides the most efficient conversion of this supplement into milk. They reported that the positive relationship between the cost of production and milk price across the dairy industry represents a rational economic response towards maximizing gross margins.

Berger et al. (1999) studied the profitability of Argentine dairy farms to determine if profitability could be improved by either better allocation of current resources, or via farmers' growth. They concluded that there is room for improvement in resource allocation and management strategy. The current land allocation among forage and crops, and the amount of purchased feed may be changed to significantly reduce feed cost. These results are consistent with Barham et al. (1994), whose central argument is that the irreversibility of some types of investment becomes fundamental in evaluating profitability.

Brockington et al. (1983), analyzing a bio-economic model for a region in Minas Gerais State, had suggested the need for future studies to: (i) appraise the benefits of genetic improvement; (ii) analyze different breeds and genetic potential under different feed systems; (iii) conduct an economic analysis of investment and risk.

Brockington et al. (1992) studied the herd dynamics and improved pasture in small milk production farms in Brazil. They reported a high productivity response to improving pasture. The increase in production per cow is bigger when herds have higher ranges of genetic potential. In addition, they conclude that the major contribution to increased herd production comes from an increase in animal numbers. Their conclusions point to two basic implications: the relevance of the genetic potential, and the economy of size.

Abdalla, A.L. et al. (1999), reported that productivity in most Brazilian herds is low and depends on pasture. They reported that the availability and quality of pasture and the lack of supplementation limited milk production. They suggested better pasture management as a possible solution.

The literature suggests that cow performance, feed regime, production cost, cost of purchased feed, herd size and milk price are the important biological and economic variables in milk production. In addition, the interactions among them have a major impact on profits.

In addition, several studies have shown the importance of technical parameters and cow health in the profitability of milk production system. Arendonk (1985) has studied and indicated that calving interval (the time between birth of a calf and birth of the cow's next calf) is important to milk production profitability. He concluded that longer calving intervals were associated with lower average monthly net revenues during the period studied.

Faria (1996), and Dekkers et al. (1998) noted that the most important factor in milk production is cow lactation persistence because cow production and productivity increase profits.

The most economically important and frequent dairy cow diseases and health problems are those associated with mastitis (de Graaf and Dwinger 1996), cattle tick (Jonsson et al. 1998), and lameness (Enting et al. 1997). For a good review about the effects of disease on milk production, see Fourichon et al. (1999).

The literature concerning milk production systems can be summarized by the following five points:

(i) There is a tendency to increase herd size.

(ii) Cow productivity strongly impacts profitability.

(iii) Feed is the major input in the milk production system and when high quality feeds lead to a positive margin, they should be used.

(iv) The amount of resources allocated to milk production has an important effect on profit level.

(v) Cow performance and feed requirements are the central issue in the milk production system.

The general tendency in the literature is to model an existing milk production system and to analyze its performance under expected scenarios. This requires modeling a representative milk production to assure reliability and acceptability of the model results. The representative model is very important by assuring connection with the real-world problem but the solution is limited within its constrains and the extrapolation of the results is quite difficult. Several production system studies fixed the system characteristics, such as breed, feed regime, and changed scenarios analyzing the impacts of the changes on the profitability cf: Tozer and Huffaker (1999), Ramsden et al. (1999), McCall and Clark (1999), Brockington et al. (1992).

The contribution of the present work is to create a model that incorporates important Brazilian milk production characteristics and, at the same time, avoids being a prisoner of the specific *representative models* borders. Where other works fix system characteristics (for example, land, breed, productivity per cow and feed regime, etc) and simulate different scenarios, this work allowed the optimization process to determine a profitable milk production characteristic under expected scenarios. The main idea and contribution of this work is to transform fixed system characteristics in choice variables to promote the construction of a feasible system under a given scenario. Therefore, the model variables are breeds, cow productivity, size of the herd, different animal categories, size of the land, feed to be produced and bought, and complete feed regime.

The characteristics of the Brazilian milk production system, considered are: (i) land fertility, (ii) breeds available to milk production, and their technical parameters, (iii) available feeds; (iv) feeds productivity; (v) production feed cost; (vi) feed market cost.

By considering the characteristics of the system as a variable the model allowed, in the optimization process, freely interactions among biological and economic variables, constituting an interesting bioeconomic system. This is the strength of this work, and it is in accordance with Sørensen et al. (1992), Rougoor et al. (1997), Østergaard and Sørensen (1998). They affirmed that the complexity of the dairy herd involving biological and economic variables makes systemic methods necessary to gain knowledge of the dairy production as a system. Therefore, this work uses the systems approach to model a complete milk production involving a nonlinear programming theory.

Nonlinear Programming Theory

Modeling a milk production system is a difficult task. The difficulty arises because this is a bio-economic system where biological process such as milk and feed production interact with and inter-depend on economic variables such as labor, land and capital, etc. These variables and the nature of their interactions impose some conditions, which must be accounted for in the modeling of the system.

Several milk production systems have been modeled using mathematical programming. The most popular are the linear model and the classical optimization theory. However, sometimes they cannot be used. The linear model requires that the objective function and the constraint functions be linear. By modeling a milk production system, this condition could be lost and some non-linearity may be required to define certain variables or relations. In addition, classical optimization requires equality for all constraints, making it difficult to use for modeling milk production systems. Takayma (1993) recognized some differences between the classical theory (CT) and nonlinear programming theory (NPT):

(i) NPT incorporates the non-negativity constraint.

(ii) CT requires that the constraint be satisfied for all x, while NPT does not require this condition.

(iii) CT requires that the number of constraints be less than the number of choice variables, while NPT has no such requirement.

(iv) CT is concerned with the characterization of a local optimum, while NPT has provisions for the characterization of the global optimum.

Second-order sufficient condition or (BHC)[6] is required only for a particular point x, while the quasi-concavity pertains to all 'x'. This means that BHC is concerned with a local optimum while quasi-concavity is concerned with a global optimum.

For the classical theory, BHC requires that the bordered Hessians determinant alternate in sign with strict inequalities as it pertains to a unique optimum. Corresponding to this, the strict quasi-concavity[7] of the objective function plays a central role in establishing the uniqueness of the optimum in non-linear programming theory.

The quasi-concavity condition used in NPT enables us to obtain a more transparent economic interpretation than does BHC in CT.

The Quasi-concavity is stated as:

$f[\alpha x_i + (1-\alpha)x_j] \geq Min\{f(x_i), f(x_j)\}$ for all $x \in S$ and α [0,1]. (1)

Where S is a subset of R^N.

[6] For detail of the Bordered Hessian Conditions (BHC) see Takayma p. 114.

If a solution can be found in Classical or Nonlinear theory, it will be useful to understand its form. The solution can be a local (L) or global (G) solution. The global solution is the optimum (maximum or minimum) solution over the entire set, say set 'S'. The local solution is an optimum (maximum or minimum) in a certain neighborhood in the set 'S'. It is clear that G implies L while the converse does not necessarily hold. However, if the constraint set 'S' is convex[8], we have:

(i) Every local maximum (L) is also a global maximum (G) if the objective function f(x) is explicitly quasi-concave.

(ii) Every local maximum (L) provides a *unique* global (G) maximum if f (x) is strictly quasi-concave.

The basic characterization of the optimum in nonlinear programming can be done by the First-Order condition (FOC) and by using the Saddle-Point condition (SPC). Under FOC, the Lagragian plays an essential role, and we have:

$$f(x,\lambda) = f(x) + \sum_{j=1}^{m} \lambda_j g_j(x) \tag{2}$$

Where the g_j are the constraint functions, and λ_j are the Lagragian multipliers j = 1, 2, …, m. the FOC for the optimum is found in terms of the first-order derivatives of the Lagragian.

$$\frac{\partial f(x^* \lambda^*)}{\partial x_i} \leq 0,\ \frac{\partial f(x^* \lambda^*)}{\partial x_i} x_i = 0 \text{; and i = 1, 2,…,n.} \tag{3}$$

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[2] For detailed explanation about quasi-concavity see Andrew Mas-Edel et al. (1995) p. 934.

[8] The convexity of the constraint set 'S' is guaranteed if all constraint functions are quasi-concave. For good explanation about convex sets, see Mangasarian (1969-chapter 3).

$$g_j(x^*) \geq 0, \quad and \qquad \lambda^*_j \frac{g_j(x^*)}{\partial \lambda_j} = 0 \text{ j} = 1, 2, \ldots, \text{m} \qquad (4)$$

An inequality appears in equation (3) because it is the required condition for $x^*=0$ for some or all i. This is referred to as the *corner* solution. Referring to Takayma (1999), this condition is met in the classical optimization when the FOC is only equal to zero and only the *interior* solution is provided.

One important problem in the theory of constrained optimization is the relationship between the optimality condition for global (G) or local (L) solutions and the FOC. Takayama (1993) mentions that FOC is neither necessary nor sufficient for an optimum. However under concavity for maximum (both objective and constraints are concave functions) or convexity for minimum optimum (both objective and constraints are convex functions), the FOC imply a global optimum (G), since there are the following conditions: $x \geq 0 \quad such \;\; that \quad g_j(x) > 0 \qquad j = 1,2,\ldots,m.$ (5)

The condition stated in (5) is known as the *Slater* condition. When it holds the FOC provides necessary and sufficient conditions for the global optimum. According to Takayama (1993), in the optimizing process under the Slater and concave/convexity conditions, the second order condition is not necessary.

In addition, Arrow, Hurwicz, and Uzawa (1961) propose that (FOC) is necessary for (L) provided that at least one of the followings conditions holds:

(i) The constraints $g_j(x)$ are all convex or linear functions.

(ii) The constraints $g_j(x)$ are all concave functions and the Slater's condition holds.

(iii) The constraint set 'S' is convex and possesses an interior solution and the first derivative of the constraint $[g'_j(x^*)] \neq 0$ for all 'j' $\in$ 'C', where 'C' is the set of all effective constraints at x^*.

The rank of $[g'_j(x^*)]$ 'j' $\in$ 'C' equals the number of effective constraints at x^*, where it is assumed that the rank condition holds. The rank condition relates the number of constraints (m) to the number of variables (n), where the number of constraints (m) should be less than the variables (n).

The previous proposition ensures that (FOC) is necessary for a local optimum (L). Arrow and Enthoven (1961), cited by Takayama (1993) state that the condition, FOC, is also sufficient for a global optimum (G). The sufficient condition for (G) is provided by the FOC if f(x) and $g_j(x)$ are quasi-concave functions and any of the following conditions are satisfied.

$$\frac{\partial f(x^*)}{\partial x_i} < 0 \text{ for at least one variable } x_i. \tag{6}$$

$$\frac{\partial f(x^*)}{\partial x_i} > 0 \text{ for some relevant variable 'i'} \tag{7}$$

where x_i is said to be relevant if there exists x_i' in set

$$S \equiv \{x \in R^N : x \geq 0, g_j(x) \geq 0, j = 1,2,\ldots,m\} \text{ such that } x_i' > 0. \tag{8}$$

The 'relevant variable' mentioned in equation 7, is one that can take a positive value without necessarily violating the constraint. (Arrow and Enthoven 1961, p.783), cited by Takayama (1993, p. 96).

$f'(x^*) \neq 0$, and f(x) is twice continuously differentiable in a neighborhood of x^*.

The function f(x) is a concave function.

Equation 7 is very important in milk production systems models because it states that marginal values of at least one factor are positive at x^*. This is expected in our study.

The other way to characterize the solution found is from the saddle-point condition. It is important since it does not require the differentiability of any functions[9]. The definition of the saddle-point is:

f(x,y) is a real-value function defined on $X \times Y$ were $x \in X$ and $y \in Y$. A point (x^*,y^*) in $X \times Y$ is called a saddle-point if:

$$f(x,y^*) \leq f(x^*,y^*) \leq f(x^*,y) \text{ for all } x \in X \text{ and all } y \in Y. \quad (9)$$

Now, suppose that the saddle-point condition holds, and we don't require differentiability of the functions. Then we have, if condition (G) holds.

$\lambda^* g(x^*) = 0.$

If the objective function and the constraints are all concave and the Slater's condition holds then condition (G) implies a Saddle-point condition.

Assume that the objective function and constraints are all concave and the Slater's condition holds, and also the saddle-point also exists, then the condition (G) holds and $\lambda^* g(x^*) = 0.$

If the objective function and the constraint functions are all continuously differentiable, then the saddle-point condition implies FOC.

If the objective function and the constraint functions are all continuously differentiable, FOC implies a saddle-point condition if all functions are concave.

Beyond the nonlinear and classical optimization the milk production system can

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[9] Takayama (1999) p.106

be modeled using dynamic and static, stochastic and deterministic models. The technique to be used largely depends on the objective of the study. If the intention is to model a growth process, the dynamic model is indicated. If some parameter has an important uncontrolled variation, the model can incorporate the stochastic process. In addition, the numerical optimization techniques used to find a solution can be chosen from several different techniques. The necessary assumptions here are that when the set of solutions is applied to a real-world problem a reliable outcome is predicted.

Numerical Optimization Techniques

The use of numerical optimization techniques in simulation is a developing field. There are many available algorithms in different software packages and some are more suited for specific problems. To solve a multi-dimensional real-world problem, such as the milk production system, an efficient optimization method is required, and various numerical techniques have the potential to provide an adequate solution. Parsons (1998) and Mayer (1999) citing several authors, included hill-climbing and other gradient-type methods, direct-search algorithms including the simplex method, hybrid targeted methods, evolutionary strategies, genetic algorithms, simulated annealing and Tabu search. His conclusion was "Unfortunately most (if not all) of these methods experience difficulties when faced with the multidimensional models of the real world system,..."(Mayer 1999, p. 114). Mayer (1997) also has discarded the Tabu search for application to a multi-dimensional system with continuous independent variables because it has methodological flaws when applied to this kind of problem. He stated that only genetic algorithms and evolutionary strategies can provide good results when applied to a complex optimization process.

However, by nature and derivation, gradient-type methods have definite theoretical and practical shortcomings when applied to optimizations. The major problem of the gradient-type method comes from its design. It converges on the closest optimum point guaranteeing only a local optimum. Where the local optimum is an adequate response, this method performs well enough. However, if a global optimum is required its performance is highly dependent on the starting values.

This work uses the Quasi-Newton (hill-climbing) model in MINOS 5 in GAMS. It was chosen because of its great capacity to deal with big models. While the Quasi-Newton converges quickly to the closed maximum, its major problem is the set of starting values. If the nonlinear objective and constraint functions are concave (convex) within this region, any optimal solution obtained will be a *global optimu*m. Otherwise there may be several local optima, and some of these may not be global. In such cases the chances of finding a global optimum are usually increased by choosing a starting point that is "sufficiently close" to the global optimum. If we have the starting value close to the global optimum, than the model will converge to a global optimum. To find the 'ideal' starting values, a loop function (GAMS a user's guide p. 154) was constructed to find the starting values that led to a higher solution for the model. By using the starting values that give this higher solution the Quasi-Newton has a high likelihood of converging upon a global solution, and thereby addressing the difficulties explained by Mayer (1999).

In brief, the major problems in the milk production system are the cows productivity, feed cost, land use, capital allocation, fixed costs, and herd size. The characteristics of the mathematical model and its technique largely depend on the work objective and it is expected that a nonlinear programming technique is likely to be the most suitable mathematical approach to understanding this complex real-world problem.

CHAPTER III

CONCEPTUAL FRAMEWORK

Introduction

The Brazilian milk producers have been facing a reduction in profit due to a systematic reduction in milk price and low productivity. Gomes (1998) reported a decrease of 47% in prices received by producers from July 1994 to January 1998. This decrease in prices had a negative impact on profit levels. There are several possible reasons to explain this milk price reduction and resulting decrease in profit. There are reasons for this on both sides of the farm gate. Beyond the farm, they lie in the demand, supply and in government actions. Inside the farm, reasons for loss of profit reside in inefficiencies in the production unit side.

The size of the market is the most important issue on the demand side. The Brazilian market is small because of a chronic wealth concentration, which has left important segments of the population out of the consumer market. This is reflected in the dairy products consumption level, and impacts the processing firms' fluid milk demand. The problem caused by the small demand is aggravated by the import of dairy products that are subsidized at the point of origin. Import of these subsidized dairy products when the demand growth or the supply is low causes the milk price to remain low. This import schedule is not likely to change since it is part of the Brazilian government strategy to maintain economic stabilization. In this plan, low food price is considered important.

Another possible cause of declining profits, in the milk demand side, is market imperfection. Gomes A. (1999), suggested that the dairy industry in Brazil could have imperfect competition. Jank and Galan (1997) observed that more than one half of dairy processing firms existing in 1981 were bought or joined in partnerships characterizing a clear tendency towards concentration processes. This observation about the market imperfection is very important because market deregulation lets the milk price to be formed in the market environment. Imperfect competition allows the market to create serious problems for the milk farmers. However, there is no conclusive work about the effect of market power on the dairy industry in Brazil, and this issue should be addressed in future research.

Beyond the import schedule, government actions such as credit lines, interest rates, taxation, sanitary legislation, regulations and control, can all be important sources of decrease in profit. The sanitary legislation, for example, has been changing and now includes rigorous requirements for production methods in order to guarantee better milk quality. One of the most important of these requirements is the refrigeration of the milk while it is on the farm. This requires considerable new investment by the farmer and increases the fixed cost.

The milk supply is the second reason for a decrease in profit. Jank (1994), and Jank and Galan (1997) affirmed that the lack of long-term contracts is one of the most important sources of uncertain supply variation in dairy production. Since long term contracts do not exist, producers deliver their product on monthly or daily price bases without previous agreement. If the long-term contract can be shown to be important, it could become part of supplier – processor agreements. This may not always improve the profit picture however, as it could also perpetuate lower prices if the negotiation goes against the farmer. Therefore, the negotiation capacity and ability of the farmer are big factors in deciding whether or not long-term contracts pose an adequate solution to the need for profitable and stable prices. These negotiations have become more difficult because milk farmers' organizations have lost much of their strength following the market deregulation. In addition to the weakness of their organizations, there are more than one million milk producers, geographically disperse, with different interest, making the organization and negotiation processes expensive and difficult.

The reasons for declining profits are many. However, there can be no permanent solution for the dairy sector in Brazil without strong and well-structured farmers' organizations. These organizations are mandatory for helping the farmers not only in formal long-term contract negotiations but also for representing them in government forums.

While there are many reasons for declining profit that are outside the farm, as has been discussed above, there are also reasons for declining profits within the farm itself, particularly within the milk production unit. The most important problems in the milk production units in Brazil are the non-specialized breeds, deficient feed levels, sanitary cares (Alves 1996, Jank 1998, Gomes A. 1999), and poor managerial strategies (Alves 1996, Jank 1998). The typical Brazilian milk producer uses a dual – purpose cow with middle to lower specialization. These animals are supplied with a deficient feed regime under tropical conditions. As a result, the milk production is inefficient and shows low productivity.

Since this work assumes that farmers are professional and price takers in input and product price, the way to increasing profit lies in improvements on the production side. It is also assumed that farmers are or want to be specialized in milk production.

Milk Production Optimization Assumptions

On the production side, a solution can be found because farmers have control over several production variables and can freely make changes. The changes needed to increase profits depend on the farmers own desires, and do not need, depend on or interact with other economic agents necessarily. Farms can increase profit by, for example, increasing the quantity produced or decreasing the production costs. There are several relevant variables that farmers may exploit to increase their profit level.

Under the price taker condition, the farmer cannot change or influence the input or output price, and so they cannot use these to improve profit. Since it is assumed that farmers are profit maximizer economic agents, controlled variables must be found in the profit function. Thus, we have:

$$\pi = P * f(x_1, x_2, \ldots, x_n) - \sum_{i=1}^{n} r_i * x_i - b \quad (1)$$

Where: (π) is the profit function; (ii) P is output price; (iii) f (x_i) is the production function; (iv) r_i is the input 'i' cost; (v) x_i is the amount of inputs used; (vi) b is fixed cost.

The first order condition for maximum profit is given by:

$$\frac{\partial \pi}{\partial x_i} = P * \frac{\partial f(x_i)}{\partial x_i} - r_i = 0 \quad (2)$$

The partial derivative of the profit, related to the input 'x_i', should be equal to zero. This means that the value of the marginal product [$P*f'(x_i)$] should be equal to the input price (r_i). The output price (P) and the input price (r_i) are given by the farmer price taker condition. Therefore, the requirement for maximum profit shows that the profit can be increased by changing the production function $f(x_i)$, that is by changing the technology. The production function has a fixed ratio of inputs used to a fixed amount of the output produced. In our milk production case, the technology is assumed to be represented by the breed used and the milk produced by them. These represent the technology because for each breed and for each milk production level, different levels of inputs are required. Therefore, while the inputs are fixed for the same breed, producing the same quantity of milk, they are completely different for different breeds and different quantities of milk produced.

The marginal analyses conducted above assume that farmers have no excess capacity. To see if excess capacity, if it exists, could be used to improve the profit level we need look at the cost function. In the cost function, the relevance of the excess capacity can be exploited. Assume that a given technology produces the optimum output, with total cost equal to C^o, when the maximum profit condition is met. For simplicity, assume that the cost function is a linear function of the production factors (x_i) used and the fixed cost. Then we have:

$$C^0 = x_1 * r_1 + ... + x_i * r_i + b \qquad (3)$$

A given total cost (C^0), due to output produced is equal to the sum-product of the inputs (x_i) by their prices (r_i), plus the fixed cost (b). The amount of x_1 factor used is equal to:

$$x_1 = \frac{C^0 - b}{r_1} - \frac{r_i}{r_1} * x_i \qquad (4)$$

Equation 4 represents the budgets constraint for production factor 1 (x_1), given the total cost (C^0), when the profit is at a maximum using the adopted technology. The first term of equation 4 is the intercept and the second is the slope of the budgets constraint for production factor 1. The equation 4 shows that, given the technology, the amount of input x1 can be increased only by changing the intercept, since the slope is given by the technology used and the market price of production factors. The intercept can be changed only by changing the fixed cost 'b', because the others variables are not under the farmer's control. A decrease in fixed cost is possible if there is some excess capacity, which is assumed to be optimum in the previous analyses. Therefore farmers could decrease their cost or increase the amount of input used, and consequently the amount of output produced, under the same technology, by optimizing the allocation of the fixed resources.

The fixed resources for milk farmers are the amount of cows, the genetic potential for milk production, land and facilities. For example, if farmers have cows with genetic potential for milk production equal to 20 liters/cow/day and they produce only, say 15 liters/day; there is excess capacity of 5 liters/day. Also, if the disposable land or facilities are greater than the quantity needed, there is excess installed capacity and room for optimization of the resource allocation and resulting improved profit.

The equations 2 and 4 shows that the important variables under farmer control to improve profit are the technology, changing the input-output and input-input ratios, and/or the allocation of the fixed resources, avoiding or reducing the excess capacity, if it exists.

Milk Production Optimization Hypothesis

The variables under farmers control and the analyses above indicate two possible hypotheses about the increased profits, considering the production side solution and considering the price taker condition assumed:

Hypothesis 1: different technology from that currently adopted can improve profit.

Hypothesis 2: different resource allocation from the current allocation can improve profit

By deduction, we have a third hypothesis.

Hypothesis 3: a combination of different resource allocation and technology can improve profits.

To verify these hypotheses a milk production mathematical model, was constructed. The verification consists of simulating resource allocations, different technologies, and different combinations of them and estimating the profit level. A large profit compared to the current ones indicates the hypothesis cannot be rejected. When a hypothesis cannot be rejected it means that the variables tested could be used to improve the profit level. Thus, several simulations have been run to test the variables under the farmer's control.

Under the profit maximizer economic agent assumption, the final decision about what milk production system should be considered for the future is the one with the highest profit level.

Model Assumptions

As noted before, there are different farmers groups in Brazil. To differentiate farmers groups this work follows the Minas Gerais State Diagnostic[10] farms

[10] Minas Gerais State Diagnostic Report (SEBRAE – 1996)

classification. It classifies farms using their technological level. Therefore this work models farms, with milk production less or equal 50 liters/day (T1), representing small farms; farms producing more than 50 and less than 250 liters/day, (T2) representing the middle farms, and farms with production greater than 250 liters/day (T3) representing big farms.

To model a complex system some simplifications are needed. Beyond these assumptions, it is assumed on the farmer side that: a) farmers are price takers in both input and output markets. b) Farmers are professional, specialized and rational economic agents. c) Farmers have an initial investment capacity equal to the value of the current endowment. d) The farm endowment is the set of facilities, herd size with their genetic potential, and disposable land. e) There is no difference in productivity between hired and family labor. f) Dairy cow performance is a function of environmental conditions, feed regime and technical parameters. g) The cow nutritional requirements must be fulfilled. h) The nutritional requirements for milk production are in fixed proportions for six nutrients (protein, energy, TDN, calcium, phosphorus, and potassium). This assumption is supported by the Net Carbohydrate and Protein System from Cornell University and by the Nutrient Requirements of Dairy Cattle from National Research Council (NRC). i) There is no substitutability among the required nutrients. j) The milk production is a linear bio-economic Leontief production function. l) The ideal calving interval is equal to 12 months.

In addition, the market environment conditions are: a) Brazil continues to open the internal market b) the government does not intervene directly in the dairy market c)

The concentration of processing firms and production factor suppliers continues to increase. d) Farmers continue as price takers.

Farms can change technology in order to increase profit. Breeds and their genetic potential for milk production, represent technology. In Brazil, there are six important breeds for milk production: Brown Swiss, Crossbreed Holstein-Zebu (CrossHZ), Gir, Guzerat, Holstein and Jersey. Therefore there are six possible breeds to be chosen, and each has a specific production capacity, meaning a different technology level.

In addition, farms can make different resource allocations to improve profits. The resource reallocation can be done with any combination of land, facilities, and herd size. Resource allocation and technology change is constrained by the total endowment value in each farm category. For simplicity investment in facilities is assumed to be a fixed amount per head, so becoming a function of the herd size.

Beyond the previous assumptions, this works assumes a milk production composed of three enterprises. (i) Milk enterprise, (ii) Replacement enterprise and (iii) Land enterprise. Each enterprise has specific characteristics and endowments as described below.

Milk Enterprise (ME)

The Milk enterprise includes all adult animals of the milk production system. It considers one single breed, their technical parameters, and genetic potential for milk production. A selected breed, with specific genetic potential for milk production, represents an adopted technology and milk production capacity installed.

ME also considers facilities and equipment necessary to feed, to milk cows, and to store and keep milk cold. It buys heifers at the first calving from the Replacement enterprise and/or from the market to replace animals in the herd. The Milk enterprise is a consumer of animal feeds, so it is a customer of the Land enterprise by demanding animal feeds. But it also can buy feeds from the market. The ME choice variables are a) herd size; b) desired average level of milk production for breed 'b'. This variable is constrained by the genetic potential for milk production in each breed. c) Quantity of feeds bought from market. (It is assumed that there is an unlimited quantity of available feed in the market) d) Quantity of feeds bought from the Land enterprise.

Replacement Enterprise (RE)

The Replacement enterprise includes all young animals of the system and uses the same breed of the Milk enterprise. It also has facilities and equipment needed to grow them. It buys calves from the Milk enterprise, from the market, or from both. It grows heifers until they give birth to their first calf, at which time they are sold to the Milk enterprise or to the beef market. The male calves are grown only for the beef market. In addition, it is a customer of the Land enterprise demanding animal feed. The RE choice variables are: a) the quantity of feeds bought from the market b) quantity of feed bought from land enterprise c) heifers and steers bought from the milk enterprise, and d) heifers and steers bought from the market.

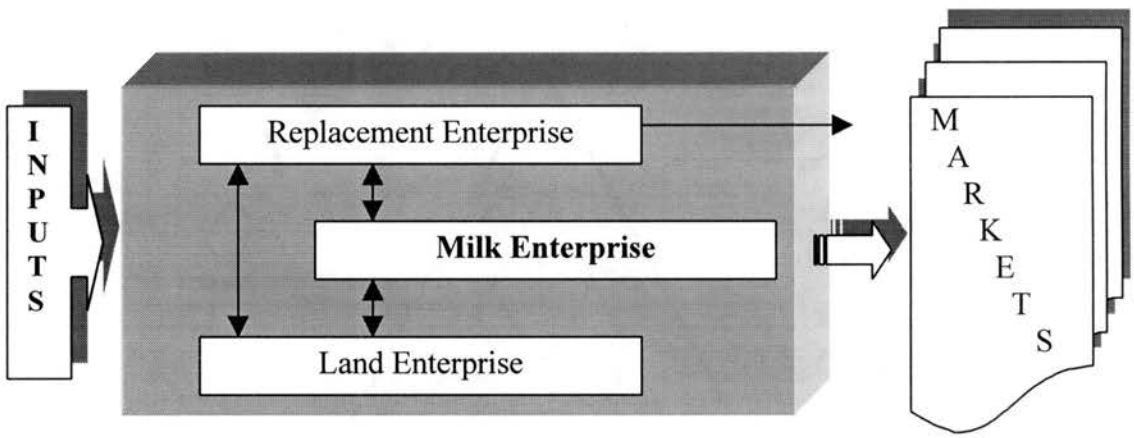
Land Enterprise (LE)

The Land enterprise component of the model considers the land available for animal feed production. Feed production is based on the demand from the other two enterprises. The choice variables for this enterprise are the quantity of feed 'f' to be produced, and the resulting amount of land to be bought or used in the Land enterprise.

The following schematic system shows the three enterprises, the relationship between them and the relationship they have with the market:

FIGURE 10

SCHEMATIC REPRESENTATION OF THE MILK PRODUCTION SYSTEM



The milk production system (gray area) was divided into three subsystems or enterprises. The milk enterprise is considered to be the most important enterprise, and the others are subsidiaries to it. The arrows show the relationships between them and the arrows going out of the system refer to products sold to the market. To build new milk production system with optimized resource allocations and better technologies the mathematical model, showed in chapter IV, permits selection of the variable choices under the constraint of the endowment value.

CHAPTER IV

METHODS AND PROCEDURES

Introduction

The market deregulation in 1991 and the economic stabilization plan are indicated as the most important reasons to explain the extensive transformations in the dairy industry in Brazil. The most important consequence of these changes is reduction in profit for dairy farmers.

To the extent milk producers are price takers, increasing profits can be done only through implementing better resource allocation and/or improved technologies. Thus, the present work attempts to select a combination of production factors and technologies that provide more profitable milk production systems, under different scenarios, to predict the characteristics of the most likely Brazilian milk production system in the future.

Method

The method used is a nonlinear mathematical model, representing a one-year time horizon, and simulates resource allocation and change in technologies. The model has profit as an objective function and resource allocation and technologies as choices variables. The simulation results are the expected profit under scenarios established and change conducted (resource allocation and/or technologies). The combination of resource allocation and technology that yielded the highest profit was considered the better milk production system.

In addition, to start the process it was assumed that farmers sold their existing farms and the value obtained is the capital investment capacity. Therefore farmers can reorganize the system by buying new technologies and resources constrained by the amount of the investment capacity. Additional assumptions were:

(i) Farmers are rational economic agents searching for the system that maximizes returns to fixed resources.

Farmers can chose several strategies. They can reorganize the allocation of scarce resources, change technologies or they can do both to find profitable milk production systems in the Brazilian market and environment conditions.

(ii) Farmers have an initial capacity to invest, which corresponds to the current endowment value.

(iii) Farmers can change resource allocation, corresponding to herd size, amount of disposable land and facilities.

(iv) Farmers can change technologies, corresponding to breeds and their genetic potential for milk production. . There are six different breeds available to produce milk in Brazil: 1) Brown Swiss; 2) Crossbreed Holstein-Zebu (CrossHZ); 3) Gir; 4) Guzerat; 5) Holstein and 6) Jersey.

Other model assumptions include:

(v) One-year time horizon, with a milk production system composed of three enterprises: Milk, Replacement and Land enterprise.

(vi) The animals' nutritional requirements are a function of their technical parameters, physical environment and amount of milk produced.

(vii) Animal nutritional requirements must be fulfilled.

(viii) Milk production requires a fixed proportion of six nutrients: protein, energy, tdn, calcium, phosphorus, and potassium, and is a linear function.

(ix) No substitutability among nutrients, implying a Leontief production function.

(x) Three categories of cows are used in the Milk enterprise. Mature cows (qcm_b), lactating cows (qcl_b), and pregnant (qcp_b) cows. Farmers can invest in mature cows, the quantity of which equals the herd size.

(xi) Six animal categories are used in the Replacement enterprise. They are classified by gender – heifer (female) and steer (male) – and by age (zero, one and two – year old). The farmers can invest in heifers and steers that are zero or one – year old.

(xii) Forty-five different feeds are available, each with its own nutritional characteristics, average production per hectare, fixed production cost, and market price.

In addition, three farm size categories are considered. These categories are related to farm size classifications as reported in the Minas Gerais State Diagnostic[11]. Farm size categories are related to the quantity of milk produced. They are reported in three levels according to their milk production per day. Each has different inventory, technological and economic parameters. Thus, the investment capacity among the three categories is different. Therefore, the same strategy can have different response for each farm category

[11] Idem (SEBRAE – MG 1996)

due to the investment capacity. The first level (T1) refers to farms with milk production less than 50 liters/day and corresponds to small farms. The second level (T2) refers to farms with milk production between 50 and 250 liters/day and corresponds to middle – sized farms. The third level (T3) refers to farms with milk production greater than 250 liters/day and correspond to big farms. Thus, each of these three farm categories has one model where resource allocation and change in technology is tested.

The first step is to create a base model that represents each of the farm categories. To do so, a model with a similar number of mature cows, same breed, same average milk production per cow (cow productivity), similar number of growing animals, and the same disposable land was created. The profit of these representative models is expected to approximate the amount of profit realized for farmers in each category.

These models were simulated in order to accomplish the first specific objective of this work, to 'evaluate profitability of the current milk production system and identify specific causes of inefficiency'. The simulations of each of the three farm categories calculated marginal values, elasticity, profit level, break-even volume and investment return rate.

To fulfill the second specific objective ' to evaluate profitability of alternative milk production system under possible future environment', several simulations were conducted under a range of expected future scenarios.

Scenario One

The first scenario assumes a stable economy with an annual inflation rate of 4.5%, an annual interest rate of 6%, a milk price equal to US$0.19/liter, and no government intervention. In this scenario, we have the following simulations:

Simulation 1. The representative model increases labor cost 50%. Labor cost is expected to increase due to a reduction in the rural population, among other reasons. This simulation is addressed to help the calculation of the labor elasticity of profit.

Simulation 2. The representative model considers change in 50% of the investment capacity. This simulation helps to find the capital elasticity of profit in each farm level.

The first and second simulations are linked to the first specific objective of this study and help to explain the current performance and inefficiency. The following simulations were addressed to the second specific objective, to evaluate a profitability of alternative milk production system.

Simulation 3. The model considers optimization of the resource allocation with no change in technology. Since breed and average milk production per cow represent technology, the model considers crossbreed Holstein-Zebu because it is the major breed used in Brazil. Average milk production per cow was assumed to be the current milk production average found in each farm category. The choice variables are the herd size, the number of growing animals, land, feed regime and facilities, constrained by the investment capacity. This simulation addresses to the first hypothesis that resource allocation can improve profit.

Simulation 4. The model considers optimization of resource allocation and change in technology. There are six major milk – producing breeds in Brazil, with several milk production levels. Therefore, the choice variables are breed, average milk production, herd size, number of growing animals, land, feed regime and facilities, constrained by the investment capacity. In addition, this simulation assumes milk production of each breed equals the average found currently in Brazil and reported by Martinez (2000). Therefore, the farm can change from its current technology to another technology already available in Brazil. This simulation addresses to the second and third hypothesis that resource allocation and change in technology can improve profit.

Simulation 5. The model considers optimization of resource allocation and change in technology. However, the optimization allows for an increase in milk production per cow, approaching the genetic potential, which goes close to genetic potential for each breed reported in the National Dairy Cattle Technical Records Archive. This productivity increase should be understood as more aggressive technology that may demand research and substantial and drastic transformation in dairy farms to be technically available and economically feasible. The choice variables are breed, average milk production, herd size, number of growing animals, land, feed regime and facilities, constrained by the investment capacity. This simulation addresses to the second and third hypothesis that resource allocation and change in technology can improve profit.

Scenario Two

The second scenario assumes a stable economy with an annual inflation rate of 4.5%, interest rate of 6%, milk price of US$0.15, and no government intervention. This scenario represents the ongoing decrease in milk prices.

Simulation 6. The model considers optimization of resource allocation and change in technology for breeds that were profitable under the first scenario. Therefore, the choice variables are breed (choosing from those achieving positive profit in simulation 5), average milk production, herd size, number of growing animals, land, feed regime and facilities, constrained by the investment capacity. This simulation is an important test of milk production systems under decreasing milk prices. In addition, it allows calculation of elasticity of profit and production factors with respect to milk prices.

Scenario Three

The third scenario assumes an economy with inflation rate equal to 10.5%, interest rate 12%, milk price US$0.15/ liter, and no government intervention. This scenario represents the ongoing decrease in milk prices, as well as increase in the inflation rate (represented by an increase in the discount rate).

Simulation 7. The model considers optimization of resource allocation and change in technology for breeds that were profitable under the first and second scenarios. The choice variables are breed, average milk production, herd size, number of growing animals, land, feed regime and facilities, constrained by the investment capacity. This simulation is an important test of milk production systems under decreasing milk prices increased inflation. In addition, it allows calculate of elasticity of profit and production factors with respect to an increase in the discount rate.

All simulations were conducted for the three farm categories. Table 10 summarizes the scenarios and simulations. Results provided by the simulations under the different scenarios are marginal values, elasticities, break-even volume and profit level.

The goal of these simulations is to identify for each scenario a technology and resource allocation that maximizes profit under the assumptions. A schematic representation of the method used is provided in Figure 11.

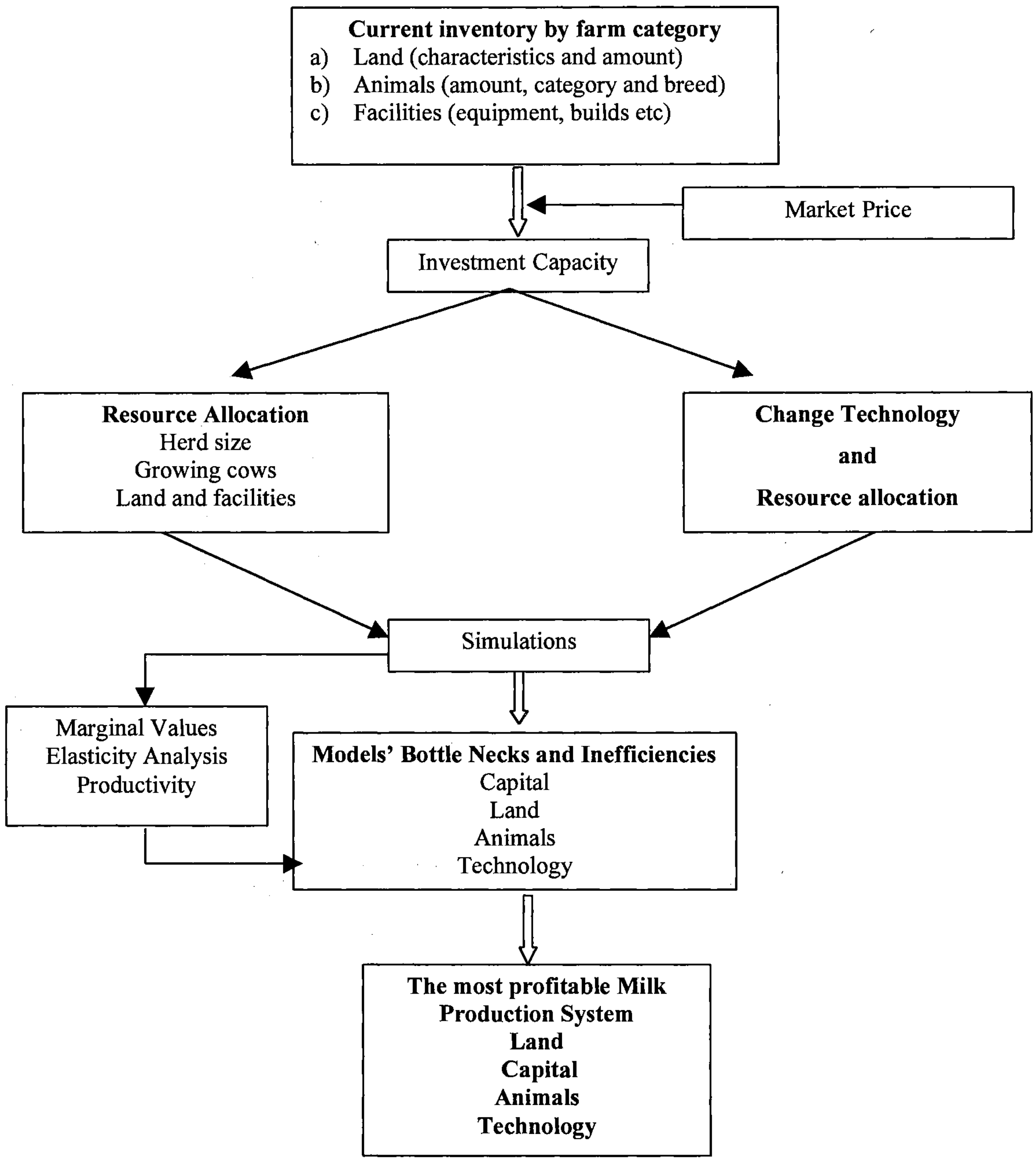
TABLE 10

SUMMARY OF SCENARIOS AND SIMULATIONS

Scenarios and Simulations	Changes	Constraints	Choice Variables
First scenario	**Milk price $ 0.19 interest rate 6%**		
Simulation one	Increase 50% labor cost	Representative model	Feed regime
Simulation two	Increase 50% investment capacity	Representative model	Feed regime
Simulation three	Change resource allocation	Breed and cow productivity, investment capacity	Herd size, growing cows, land, facilities and feed regime
Simulation four	Change resource allocation and change to available technologies	Investment capacity	Breed, herd size, land, cow productivity, feed regime, growing cows, and facilities
Simulation five	Change resource allocation and use new technologies	Investment capacity	Breed, herd size, land, cow productivity, feed regime, growing cows, and facilities
Second scenario	**Milk price $ 0.15 interest rate 6%**		
Simulation six	Change resource allocation and new technologies	Investment capacity	Breed, herd size, land, cow productivity, feed regime, growing cows, and facilities
Third scenario	**Milk price $ 0.15 interest rate 12%**		
Simulation seven	Change resource allocation and new technologies	Investment capacity	Breed, herd size, land, cow productivity, feed regime, growing cows, and facilities

FIGURE 11

SCHEMATIC REPRESENTATION OF THE METHOD



Mathematical Model

The model assumes that the dairy farmers have control over choice variables of the three enterprises to maximize profit. The model using net present value of the one-year dairy milk production system organizes the mathematical representation of the farmers' problem as net present value for one-year milk production system for breed 'b'.

Net Present Value

$$Max\,NPV_b = M\pi_b + R\pi_b + L\pi_b \qquad (1)$$

Where, (i) NPV_b is net present value. (ii) $M\pi_b$ is Milk enterprise profit. (iii) $R\pi_b$ is Replacement enterprise profit and (iv) $L\pi_b$ is Land enterprise profit. b accounts to breed considered. The net present value discounts future income and expenses by a discount rate d.

Milk Enterprise Profit.

$$\underset{mbreed,qcm}{M\pi_b} = pmilk * qm_b[mbreed_b, qcm_b] + pbeef * qbeefM_b(qcm_b, culling_b) + \sum_{s=1}^{2} pcalves_s$$
$$* calvesM_{b,s}[qcp_b] - m\cos t_b\{f\cos tM_b(feedLM_{b,f}[n\sup M_{b,N}], feedmktM_{b,f}$$
$$[n\sup M_{b,N}]) + c\cos tM_b[invcowM_b, invLandM_b, invfacM_b, i_R] + lab\cos tM_b[qcm] +$$
$$vet\cos tM_b + o\cos tM_b + rep\cos tM_b[qcm_b, cul_b]\} \qquad (2)$$

Where:

pmilk is the milk price;
qm_b is quantity of milk produced;
$mbreed_b$ is average milk produced;
qcm_b is the herd size.
pbeef is price of beef;
$qbeefM_b$ is quantity of beef produced;
$culling_b$ is the culling rate,
pcalves is the price of calves,

$calvesM_{bs}$ is the quantity of calves produced. The subscript s equal 1 represents female calves and s equal 2 represents male calves.
qcp_b is the pregnant cows;
$mcost_b$ is the total cost in Milk enterprise;
$fcostM_b$ is the feed cost;
$feedLM_{b,f}$ is feed bought from the Land enterprise;
$feedmktM_{b,N}$ is feeds bought from market,
$nsupM_{b,f}$ is the nutrient supplied in breed 'b' using feed 'f';
$ccostM_b$ is the capital cost;
$invcowM_b$ is the investment in cows;
$invLandM_b$ is investment in land. The land bought in Milk enterprise is to construct the facilities and it is fixed and equal to one hectare;
$invfacM_b$ investment in facilities;
i_R is the interest rate;
$labcostM_b$ is the Labor cost;
$vetcostM_b$ is the Medical veterinary cost;
$ocostM_b$ is the Other cost. It considers milk transportation, taxes, fuel and energy.
$repcostM_b$ is the cost to replace a culled cow.

Milk Production Function

$$\underset{mbreed,qcm}{qm_b} = Max\{Min((n\sup M_N[feedM_{b,f}] - nother_{b,N,st}[cw_b, cphs_{st}, env]) / milk3_{b,N}[mbreed_b, qcm_b, env]), gp_b)\} \quad (3)$$

Where:

$nother_{b,N,st}$ is the nutrients required to other cow physiological stages;
cw_b is cow lived weight;
$cphs_{st}$ is the cow physiological stages (body maintenance and fetus growth);
env is the environment conditions (temperature, humidity, wind etc);
$milk3_{b,N}$ is the fixed proportion of nutrients required to produce one liter of milk;
gp_b is the genetic potential to produce milk.

The quantity of milk produced (qm_b) is the "maximum" genetically possible production for each breed 'b', constrained by the level of nutrient available. Since no substitutability between nutrients is assumed, milk production is limited by the scarcer available nutrient. The available nutrient supplied is equal to the total nutrient supplied ($nsupM_{b,N}$) from available feed ($feedM_{b,f}$), minus the required nutrients for other cows' physiological stages ($nother_{b,N,st}$). The required nutrients for other cows' physiological stages are functions of the cow weight (cw_b) and the cow physiological stages ($cphs_{st}$ –

maintenance and pregnant) and the environment (env). The animal requirements are estimated using the Cornell System[12].

Replacement Enterprise Profit.

$$R\pi_{\underset{qcr}{b}} = pheif_b * qheifRM_b + pbeef * qbeefR_b(dgainh_b, dgains_b, qcR_b) + \sum_{s=1}^{2} pcalves_s * calvesR_{b,s}[heif2f_b] - r\cos t_b\{f\cos tR_b[feedLR_{b,f}[n\sup R_{b,N}], feedmktR_{b,f}[n\sup R_{b,N}]] + c\cos tR_b[invcowR_b, invfacR_b, invLandR_b, i_R] + lab\cos tR_b[qcR_b] + vet\cos tR_b + o\cos tR_b\} \quad (4)$$

Where:

$R\pi_b$ is the Replacement enterprise profit;
$pheif_b$ is price of heifers;
$qheifRM_b$ is the quantity of heifers sold to Milk enterprise;
$qbeefR_b$ is the quantity of beef produced;
$dgainh_b$ is the daily gain for heifers;
$dgains_b$ is the daily gain for steers. The daily gains for heifers and for steers are calculated using the formulas adopted in the Cornell System[13].
qcR_b is the herd size in Replacement enterprise;
$calvesR_{b,s}$ is the quantity of calves produced where subscript 's' equals to 1 for female and 2 for male;
$heif2f_b$ is the quantity of second-year heifers;
$rcost_b$ is the total cost in Replacement enterprise;
$fcostR_b$ is the feed cost in Replacement enterprise;
$feedLR_{b,f}$ is the quantity of feeds bought from Land enterprise;
$nsupR_{b,N}$, is the nutrient supplied in Replacement enterprise;
$feedmktR_{b,f}$ is the quantity of feed bought from market;
$ccostR_b$ is the capital cost;
$invcowR_b$ is the investment in cows;
$invfacR_b$ is the investment in facilities;
$invLandR_b$ is the investment in land. The land bought in Replacement enterprise is to construct the facilities and is assumed fixed and equal to one hectare.
$labcostR_b$ is the labor cost;
$vetcostR_b$ is the medical veterinary cost;
$ocostR_b$ is the other cost. It includes milk transportation, taxes, fuel and energy.

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[12] Cornell Net Carbohydrate and Protein System results in Appendix C
[13] Cornell Net Carbohydrate and Protein System Appendix results in Appendix C.

Land Enterprise Profit.

$$L\pi_{\substack{b\\feed}} = \sum_{f=1}^{45}\{(feedLM_{b,f} + feedLR_{b,f}) * tr\cos t_f - \sum_{f=1}^{45}\sum_{l=1}^{4} feedL_{b,f,l} * p\cos t_f\} \qquad (5)$$

Where:

$feedLM_{b,f}$ is the Milk enterprise feed demand for feed 'f';
$feedLR_{b,f}$ is the Replacement enterprise demand for feed 'f';
$trcost_f$ is the transfer cost and accounts to the price paid by Replacement and Milk enterprise buying feed from Land enterprise;
$feedL_{b,f,l}$ is the total feed 'f' produced in each land type 'l';
$pcost_f$ is the production cost to produce feed 'f'.

The total feed production is constrained by the land available and its characteristics. Since the Land enterprise cannot sell products to the market, the amount produced should be equal to the amount demanded. The transfer cost is equal to the production cost for feed 'f', and consequently its profit is equal to zero. This result is consistent with the assumption that the Land enterprise is a subsidiary to the other two enterprises. In addition, it is consistent with observations of milk production in Brazil where there are few examples of dairy producers selling feeds to the market.

System Constraint

The systems were optimized using General Algebraic Model System (GAMS) under the following constraints:

Investment capacity

$$invM_b + invR_b + invL_b = endow_T \quad \ldots \text{ For T=1 to 3 and b=1 to 6} \qquad (6)$$

Where:

$invM_b$ is the investment in Milk Replacement;
$invR_b$ is the investment in Replacement enterprise;
$invL_b$ is the investment in Land enterprises;
$endow_T$ is the investment capacity or the endowment value of the farm level 'T'.

Milk enterprise constraints

Genetic potential

$$mbreed_b \leq gp_b \tag{7}$$

The average level of milk production ($mbreed_b$) cannot exceed the genetic potential in breed 'b' (gp_b).

Nutrient supplied

$$n\sup M_{b,N} \geq ndemM_{b,N} \tag{8}$$

Where, the quantity of nutrient 'N' supplied in Milk enterprise in breed 'b' ($nsupM_{b,N}$) must be greater than or equal to the required nutrients demanded by breed 'b'($ndemM_{b,N}$). All required nutrients must be met.

Predicted intake

$$\text{int}\,akeM_b \leq pred\,\text{int}\,M_b \tag{9}$$

Where:

$intakeM_b$ is the total daily cow 'Dry-matter' intake;
$predintM_b$ is the predicted 'Dry-matter' intake. The intake prediction is estimated using the Cornell System.

Stabilized herd size

$$qheifRM_b,+qheifMktM_b = qcm_b * (culling_b + death_b) \tag{10}$$

Where:

$qheifmktM_b$ is the quantity of heifers in Milk enterprise bought from market;
$death_b$ is the natural death rate. This equation guarantees a stabilized herd size by equating the quantity of culled and dead cows to the amount of heifers bought from the market and from the Replacement enterprise .

Female calves produced

$$h0MR_b + h0Mmkt_b = (1 - abt_b) * qcp_b / 2 \quad (11)$$

Where:

$h0MR_b$ is the quantity of baby female calves produced in the Milk enterprise and sold to Replacement enterprise;
$h0Mmkt_b$ is the quantity of baby female calves produced in Milk enterprise and sold to market;
abt_b is the abortion rate in bred 'b'. It represents the total female calves produced in one year by breed 'b'. The model assumes a 50% probability a cow gives birth to a female calf (h0) and to a male calf (s0).

Male calves produced

$$s0MR_b + s0Mmkt_b = (1 - abt_b) * qcp_b / 2 \quad (12)$$

Where,

$s0MR_b$ is the quantity of baby male calves produced in the Milk enterprise and sold to Replacement enterprise;
$s0Mmkt_b$ is the quantity of baby male calves produced in Milk enterprise and sold to market.

Replacement enterprise constraints

Nutrient supplied

$$nsupR_{b,N} \geq ndemR_{b,N} \quad (13)$$

The quantity of nutrient 'N' supplied in breed 'b' ($nsupR_{b,N}$) must be bigger than or equal to the required nutrients demanded by breed 'b' ($ndemR_{b,N}$). All required nutrients must be met

Predicted intake

$$intakeR_b \leq predintR_b \quad (14)$$

Where:

intakeR $_b$ is the total daily calves' 'Dry-matter' intake;
predintR $_b$ is the predicted 'Dry-matter' intake. The intake prediction is estimated using the Cornell System.

Female calves produced

$$h0RR_b + h0Rmkt_b = (1 - abt_b) * heif2f_b / 2 \quad (15)$$

Where:

h0RR $_b$ is the quantity of baby female calves produced that continue in the Replacement enterprise for one more period;
h0Rmkt $_b$ is the quantity of baby female calves produced in the Replacement enterprise and sold to the market;
heif2f $_b$ is the quantity of second-year heifers. It represents the total of baby female calves produced in one year in the Replacement enterprise. The model assumes a 50% probability of a cow giving birth a female calf (h0) and the same for a male calf (s0).

Male calves produced

$$s0RR_b + s0Rmkt_b = (1 - abt_b) * heif2f_b / 2 \quad (16)$$

Where:

s0RR $_b$ is the quantity of baby male calves produced that continue in the Replacement enterprise for one more period;
s0Rmkt $_b$ is the quantity of baby male calves produced in the Replacement enterprise and sold to the market.

One-year females produced

$$h1RR_b + h1Rmkt_b = heif1f_b \quad (17)$$

Where:

h1RR $_b$ is the quantity of one-year heifers grown in Replacement enterprise and continuing the growth process for one more period;
h1Rmkt $_b$ is the quantity of one-years-old heifers sold to the market;
heif1f $_b$ is the quantity of one-year-old heifers at the end of the process.

One-year males produced

$$s1RR_b + s1Rmkt_b = steer1f_b \tag{18}$$

Where:

s1RR $_b$ is the quantity of one-year-old steers grown in Replacement enterprise and continuing the growth process one more period;
s1Rmkt $_b$ is the quantity of one-year-old steers sold to the market;
steer1f $_b$ is the quantity of one-year-old steers at the end of the process.

Two-year females produced

$$qheifRM_b + qheifRmkt_b = heif2f_b \tag{19}$$

Where:

qheifRM $_b$ is the quantity of two-year-old heifers sold to the Milk enterprise;
qheifRmkt $_b$ is the quantity of two-years-old heifers sold to the market;
heif2f $_b$ is the quantity of two-year-old heifers at the end of the process.

Two-year males produced

$$steerRmkt_b = steer2f_b \tag{20}$$

Where:

steerRmkt $_b$ is the quantity of two-year-old steers sold to the market;
steer2f $_b$ is the quantity of two-year-old steers at the end of the process.

Land enterprise constraints

Feed supplied

$$\sum_{l=1}^{4} feedL_{b,f,l} \geq feedLM_{b,f} + feedLR_{b,f} \tag{21}$$

The summation of feed produced in all land types ‘l’ in the Land enterprise (feedL $_{b,f,l}$) must be greater than or equal to the amount of feed ‘f’ bought for the Milk enterprise (feedLM $_{b,f}$) plus the amount bought for the Replacement enterprise (feedLR $_{b,f}$).

This set of equations and constraints are the basic idea of the model. Detailed variables and parameters descriptions are reported inn Appendix A (Summary of Variables and Parameters).

Procedures

Investment capacity

The idea is to build a milk production system that maximizes profit by choosing a technology and reallocating limited resources. Technology is assumed to be represented by the amount of milk produced per cow per day and the breed adopted. Thus, a system with a Holstein breed producing 20 l/cow/day is considered different technology from one with a Jersey breed producing 16 l/cow/day. This work considers farms in Minas Gerais with three different categories as described in the framework.

To build alternative systems, farmers are assumed to know their investment capacity, which is equal to the current farm inventory value. In other words, if farmers sell their current milk farms, the amount of money received will be the total investment capacity.

Each farm category has a different inventory. The categories are assumed to represent the three categories reported by the Minas Gerais State Diagnostic according to their milk production per day. The inventories are calculated considering the quantity of each asset (animal, land, and facilities), and their prices[14]. Thus, the first farm level (T1), refers to small farms producing less than 50 liters/day with an inventory value of

[14] See Farm category and inventory calculation Appendix B.

US$85,040.57. The second farm level (T2), refers to middle – sized farms producing between 50 and 250 liters/day with an inventory value of US$253,131.67. The third level (T3), refers to big farms producing more than 250 liters/day with an inventory value of US$710,939.60.

TABLE 11

FARM CATEGORY AND CURRENT ENDOWMENT

Farm	Animals			Land		Facilities	Total
Level	Heads	Milk/day	US$	Ha	US$	US$	Endow.
T1	35.67	4.10	28,417.48	40.74	33,577.09	23,046.00	85,040.57
T2	102.4	5.55	79,919.00	134.64	111,000.56	62,245.08	253,131.67
T3	283.13	8.67	248,188.58	343.23	282,883.30	179,867.72	710,939.60

The major breed in the three farm categories is the Crossbreed Holstein-Zebu. The inventory value is the investment capacity to build a different and profitable milk system and is the capital constraint for each of these 3 different categories of milk producing farms.

Production factors characteristics and prices.

The models' production factors are land, feeds, facilities, labor and breeds. The disposable land to be bought has a fixed proportion of four types with specific topography and fertility characteristics. These characteristics are important because they determine what feed can grow in a particular type of land[15]. A hundred hectares of land is assumed to include 12.29 ha of mountain (mont), 38.34 ha of hill, 37.55 ha of dry plans (Pldried); 11.91 ha of moist (humid) plan (Plhum). This proportion corresponds to the

[15] Details about feed and land type see GAMS/MINOS CODE FOR THE MODEL Appendix C.

average land characteristics in Minas Gerais State[16]. The price of one hectare is fixed and equal to US$824.18/ha[17].

The model has 45 of the most important feeds currently used in dairy milk production in Brazil. Some feeds can be bought from the market, others can be produced on the farmland and others can be from both. The feed market prices are form various source of information and the production cost is calculated from an enterprise budget spreadsheet[18]. The production cost of feeds includes fixed costs, such as capital, land and equipment, and variable costs such as fertilizer, labor, and services. The feeds produced or bought are the sources of the nutrients supplied to fulfill the animal requirements. The nutrients provided by them are calculated using the Cornell System[19].

Facilities purchased for the Milk enterprise and the Replacement enterprise are those buildings and equipment required to handle and care for the animals. For simplicity, the facilities were assumed to require a fixed investment per cow. The Minas Gerais State Diagnostic[20] reports the investment in facilities as a percentage of the total capital invested in the farm. The T1 farm level has 27.10% of the total capital invested in facilities, T2 has 24.59% and T3 farm level has 25.30%.

Labor to be hired is related to the labor productivity reported by Minas Gerais State Diagnostic. The labor productivity in farm T1 is 29 liters/person/day, corresponding to one person per each 30.51 cows, costing US$0.24 /cow/day. The labor productivity in farm T2 has 61.04 liters/person/day, corresponding to one person per each 44.36 cows, costing US$0.17/cow/day. The labor productivity in farm T3 is 94.71 liters/person/day,

[16] Idem (SEBRAE – MG 1996)
[17] This land value is currently used in Dairy Cattle National Research Center (EMBRPA-CNPGL)
[18] Feed Production Cost see Appendix C.
[19] Cornell Net Carbohydrate and Protein System Appendix C.

corresponding to one person per each 44.20 cows costing US$0.17 cow/day. The labor cost is calculated considering a monthly salary equal to US$227.50 per worker[21].

Animal Categories

The animals are the most important production factor in milk production system. There are nine animal categories considered in the model and they are allocated to the Milk enterprise and in Replacement enterprise. In the Milk enterprise, the number of mature cows (qcm_b) corresponds to herd size. All mature cows belong to this category. In addition, the number of lactating cows (qcl_b) is a function of herd size and the calving interval. Since the model considers a single production year, the number of lactating cows was adjusted to consider this model characteristic. Taking one-year calving interval as an ideal and equal to 100% of cows in lactating period did the adjustment. The 365 days (one-year calving interval) divided by the current calving interval in days, for each breed, gives the proportion of cows of each breed in lactating period adjusted to one year production for each breed 'b'. For example, Holstein has a 400 days in calving interval in Brazil[22]. The amount of cows in lactating period will be equal to 91.3%. This means that in each 100 Holstein cows in Brazil 91.3 are producing milk but 8.7 do not produce. Therefore, in each 100 cows the model takes in consideration 100 cows to evaluate the costs and only 91.3 to evaluate the production.

Another category is pregnant cows. The pregnant cow is a function of the lactating cows and the fertility rate ($fertil_b$). In the Holstein example, the fertility rate is

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[20] Idem (SEBRAE – MG 1996)
[21] See Farm category and inventory calculation Appendix B
[22] EMBRAPA – DAIRY CATTLE National Dairy Cattle Technical Records Archive.

equal to 75%[23] . Therefore, the number of cows in pregnant period, considering 91.3 lactating cows, is equal to 68.48 cows in average. It means that 100 mature Holstein cows in Brazil could produce at most 68.48 calves per year. The last category is the pregnant and dry cows. They are the same numbers of pregnant cows. The model considers one-year production with 305 days in lactating period and 60 days in dry period. These 60 days are addressed to animal recover from the lactating period and it is recommended by the EMBRAPA – Dairy Cattle in Brazil. The calves produced in the Milk enterprise do not make up as a specific category because they are sold to the Replacement enterprise or to the market when they are born. This means that they do not remain in the Milk enterprise. The farmers can invest buying only mature cows (qcm_b) for Milk enterprise.

The model uses six animal categories in the Replacement enterprise. They are related with the start age and the age that they finish the process in the one-year production system. In addition, they are related to the gender of the animal. Thus, the model has heifers (for all young female) and steer (for all young male) with zero, one and two-year-old animals. The farmer can buy heifers and steers that are zero and one-year-old. The categorization of the animals is very important to calculate the animal required nutrients, since the amount of nutrients required varies by category.

Animal Nutritional Requirements

The amounts of each nutrient required by animal were calculated using the Cornell System (CNCPS). This system is preferred to the Required Nutrients of Dairy Cattle from National Resource Council (NRC) because it adjusts the nutritional

[23] EMBRAPA – DAIRY CATTLE National Dairy Cattle Technical Records Archive

requirements according to animal characteristics and their environment. Both approaches assume a linear relation among nutrients and milk production. However, the NRC methods and tables are static and do not allow for varying some animal or environmental characteristics. The flexibility permitted by the Cornell system is very important to accommodate several Brazilian environmental and animal characteristics used in this work.

The CNCPS was evaluated by Lanna et al. (1996) and Lagunes et al. (1999) for accuracy of predictions in tropical conditions. Lanna concluded that CNCPS is superior to NRC for tropical conditions. In addition, both concluded that CNCPS can be used to accurately describe animal requirements under tropical conditions, when the feeds and cattle types can be characterized adequately to provide accurate input into the CNCPS.

In order to calculate animal nutritional requirements each animal category was represented in the Cornell System by describing its characteristics[24]. The major characteristics required in the Cornell System to calculate the animal requirements are: (i) animal characteristics (breed, days pregnant; age, lactation number, calving interval, body weight, etc); (ii) production characteristics (rolling herd average milk production, milk cow production, milk fat, milk protein, body condition score, etc) (iii) environmental characteristics (temperature, humidity, sloped distance walked, etc), (iv) animal feed mix ratio (disposable feed 'f').

After the animal characteristics are described and feed mix ratio is provided, the Cornell System optimizer finds the required balanced feed, considering rumen characteristics. It also provides the complete animal nutritional requirements.

[24] For a complete description of the characteristics, see Appendix C, GAMS/MINOS Code for the Model.

These animal requirements are used to model the milk production system for each breed. The same procedure was used for all nine animal characteristics and all six breeds.

Animal Price function

The model also has animal price functions. The price function is very important when the model needs to buy cows to optimize resource allocation. The price of cows was hypothesized be a linear function of the profit provided by them and derived from input demand theory. Therefore, the cow price is specified as a function of (i) milk produced per day (mbreed $_b$), with an expected positive sign; (ii) margin per liter of milk produced, calculated as the milk price (pmilk), on the action day, divided by the corn price. The corn price is assumed a good 'proxy' to the cost of feed due to its importance in the animal nutrition. The margin is expected to have a positive sign, since a higher margin should make cow worth more; (iii) beef price (pbeef) on the auction day, expected to have a positive sign; (iv) an opportunity cost variable (Int) equal to the interest rate on savings paid on the day of the auction.

A multiple linear regression model was used to estimate the price relationship, with 160 observations collected from two different public auctions in Minas Gerais State from 1995 to 2000. Since this is the panel data, test for heteroskedasticity and autocorrelation were conducted. The null hypothesis of homoskedastic data is not rejected at 0.01 level of significance by the White test in SAS (Table 12).

TABLE 12

HETEROSKEDASTICITY TEST FOR COW PRICE FUNCTION

R^2	# observation	White test Statistic	χ^2	Obs.
0.0339	160	5.424	6.6349	fail to reject

Table 13 shows the autocorrelation process, the parameters of the Durbin-Watson test, the order and the nature of the correlation.

TABLE 13

AUTOCORRELATION TEST FOR COW PRICE FUNCTION

Order	Dw	Pr<Dw	Pr>Dw	Obs
1	1.8143	0.0669	0.9331	positive auto-correlation
2	2.0590	0.5631	0.4369	no auto-correlation
3	1.4981	0.0004	0.9996	positive auto-correlation
4	1.7510	0.0563	0.9437	positive auto-correlation

The Durbin – Watson test for autocorrelation shows positive correlation in order 1,3 and 4. An AR(1) model was used to correct for autocorrelation. The maximum likelihood estimator suggested by Judge et al. (1985) was applied and the results show that all parameters are significant at the 7.0% level of significance or better. The total R^2 is equal to 0.69 indicating that the model fits the data. The estimated model is:

Mature cow price

$$\begin{aligned} Pcow_b &= \underset{(1265)}{-2485} + \underset{(11.40)}{37.0567} * mbreed_b + \underset{(131.57)}{633.6802} * Milkcornratio + \underset{(658.99)}{2478} * pbeef_b \\ &\quad - \underset{(411.67)}{742.07} * \text{int} \end{aligned} \qquad (22)$$

Where:

$Pcow_b$ is the price of mature cow;
$mbreed_b$ is the desirable daily milk production (cow productivity);
Milkcornratio is the milk-corn price ratio;
$pbeef_b$ is the beef price,
int is the interest rate.

As an example, a Holstein cow producing 20 liters/day, bought in public action in Minas Gerais State, when milk price is US$0.16 per liter, corn price is US$0.12 per Kilo, beef price is US$1.00 per kilo and the interest rate is equal to 0.5% per month, it has an expected price of US$1,208.00. The regression results show that for each additional liter of milk produced per day, the cow price increases by US$37.06, for one-unit increase in the milk-corn price ratio the cow price increases by US$6.34, and for a one-cent-per-kilo increase in beef price, the cow price increases by US$24.78. However, for each percentage increase in interest rate the price decrease by US$74.21. The same price function is assumed for all breeds, however, a key variable that is likely to differ by breed is milk production per day, and the regression results indicate that producers will pay a higher price for cows with higher productivity.

The heifer price function was specified as a function of the milk produced by its 'Mom' – the expected milk production for the heifers – and the milk price on the day of the auction. Heifers are an important animal category because they will replace a cow in the Milk enterprise. The regression used 97 observations collected from different public auctions in Minas Gerais State from 1995 to 2000. Since this is panel data, tests for heteroskedasticity and autocorrelation were conducted. The null hypothesis of homoskedastic data was rejected by the White test in SAS at 0.01 level.

TABLE 14

HETEROSKEDASTICITY TEST FOR HEIFERS PRICE FUNCTION

R^2	# observation	White test Statistic	χ^2	Obs.
0.1137	97	11.0289	6.6349	reject H0

Assuming the heteroskedasticity is proportional to milk production the model was corrected by transforming the data by the variable milk production. In addition, the Durbin-Watson statistics shows the existence of autocorrelation in the set of data used.

TABLE 15

AUTOCORRELATION TEST FOR HEIFERS PRICE FUNCTION

Order	Dw	Pr<Dw	Pr>Dw	Obs
1	1.4952	0.0038	0.9962	positive auto-correlation
2	1.3086	0.0002	0.9998	positive auto-correlation
3	1.6335	0.0420	0.9580	positive auto-correlation
4	1.7565	0.16	0.8400	no auto-correlation

The Durbin – Watson test for autocorrelation shows positive correlation in order 1,2 and 3. An AR(1,2) model was assumed and the data was corrected using the maximum likelihood estimator suggested by Judge et al. (1985). The results show that all parameters are significant at 1.54% or better. The total R^2 is equal to 37.62% showing that the model fits the data reasonably well. The estimated model is:

Heifers Price

$$\underset{}{pheif_b} = \underset{(1567)}{-4433} + \underset{(21.11)}{52.1331} * mbreed_b + \underset{(8899)}{30251} * pmilk \tag{23}$$

Where:

$pheif_b$ is the price of two-year-olds heifer;

pmilk is the milk price in the action day.

As an example, a Guzerat heifer with Mom's milk production of 7 liters/day, bought in public action in Minas Gerais State when the milk price is equal to US$0.16, receive a price of US$772.10. The heifer function shows that for each additional liter of expected milk production the heifer price increases by US$52.13 and an one-cents/liter increase in milk price increases the heifer price by US$302.51. Again the same price function is assumed for all breeds, but since the milk production for each breed will typically be different, it is expected that the prices of heifers will be different for each breed 'b'. There are three categories of heifers, however, the equation (23) is valid only for heifers ready to be transferred to the Milk enterprise. These heifers are two-year-olds birthing their first calves and replacing cows in the Milk enterprise. For simplicity, it was assumed that a one-year-old heifer's value is one half of the price of two-year-olds, and the value of a baby heifer is equal to its birth weight times beef price.

The steer price is calculated by multiplying the weight of a mature cow in breed 'b', times the beef price (Pbeef), which is fixed at US$0.6056 per kilo[25]. This price is valid for steers at the end of their time in the Replacement enterprise, or two-year-old male animals. For simplicity, it was assumed that a one-year-old steer is a half price of a two-year-old steer, and the value of a baby steer is equal to its birth weight times the beef price.

Procedural analyses

To achieve the first specific objective of this work – to evaluate profitability of current milk production systems and identify specific causes of inefficiency, the model used the results from simulation 1 and 2, and the analyses indicated in the method.

To attain the second specific objective of this work – to evaluate profitability of alternative production systems under possible future environments – the model used the results reported in the other simulations and the marginal values and elasticities. These simulations account for the impacts on profit from changes in the resource allocation and/or change in technical and economic parameters.

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[25] Beef Prices average from 1996 to 2000 in Brazil ESALQ/BM&F

A set of basic information for each of these simulations is reported. It covers the choice variables and the adopted combinations of the production factors capital, land, feed and their nutrients. In addition, amount of milk produced, animal production costs and profit level is reported for each system.

By comparing the profitability levels, the break-even volume of milk production, marginal values and elasticities the model identifies the impact on profit from changing in the most important parameters and variables. This comparison is conducted for each milk production system, for each farm category, and for each simulation. In addition, it constructs a picture of the future milk production systems, giving their breeds technologies and resource allocation.

The model was optimized using MINOS 5 in GAMS. Therefore, each result reported came from an optimization of the model adjusted to fit the expected characteristics for such simulation. The simulation results are the expected farm's gain under the scenario condition imposed.

The results are reported in terms of which systems are profitable, and which is the most profitable considering the assumptions and scenarios assumed and the set of feeds with potential to be explored in the future.

Technical parameters and major characteristics of CrossHZ, Guzerat, Gir and Holstein came from EMBRAPA – Dairy Cattle, Genetic Improvement Program and the National Dairy Cattle Technical Records Archive. Jersey and Brown Swiss data were obtained from the respective breed associations. The information about feeds, their production average and costs came from EMBRAPA and from Brazilian literature.

Several statistical data from FAO Statistic, Brazilian Geography and Statistics Institute, ESALQ/Future Market Sao Paulo Board of Trade were also used.

CHAPTER V

RESULTS AND DISCUSSION

The Representative Model

The problem faced by milk producers in Brazil is reduced profits. The solution to this major problem suggested by this work is better resource allocation and/or adoption of more productive technologies.

The hypotheses which lead to this solution were: (i) adjusting resource allocation can improve profit; (ii) adopting different technologies can improve profit and (iii) the combination of improved resource allocations and different technologies can together improve profit.

In order to evaluate the hypotheses, a mathematical model was constructed incorporating important characteristics of milk production, in order to simulate resource allocations, different technologies, and different combinations of them in order to estimate the expected profit level.

Three different sizes of farms were considered. The first, farm T1 had milk production less than 50 liters per day, and corresponded to small farms. Farms with greater than 50 and less than 250 liters, represented by farm T2, correspond to middle – sized farms. Farms with milk production greater than 250 liters, represented by farm T3, corresponded to large farms.

These three farms levels correspond to the milk farmer categories adopted in the Minas Gerais State Diagnostic (SEBRAE – FAEMG 1996). The three farm sizes were simulated by optimizing a model that fixed the amount of land, the amount of capital invested in mature cows, and the level of milk production per cow to be the same for each farm size as the average for each of the three categories in the Minas Gerais State Diagnostic. Parameters for each of the three size categories, in the representative model, are shown in Table 16.

TABLE 16

DESCRIPTION OF THE MILK PRODUCTION SYSTEM REPRESENTATIVE MODELS

Variables	Farm T1 (50 liters/day)	Farm T2 (50< liters/day <2 50)	Farm T3 (liters/day > 250)
Endowment value ($)	85,040.57	253,131.67	710,939.60
Mature cows (head)	15.50	40.03	111.19
Lactating cows (head)	13.50	34.87	96.85
Cow productivity (liter/day)	4.10	5.55	8.67
Growing cows (head)	31.77	105.66	312.63
Land (ha)	40.74	134.64	343.23
Major breed	CrossHZ	CrossHZ	CrossHZ
Major Feed	Elephant Grass	Elephant Grass	Elephant Grass

(i) Data generated by constrained optimization. (ii) CrossHZ (Crossbreed Holstein – Zebu).

There are two differences between current milk production in Minas Gerais State and the representative model shown in the Table 16. First, the representative models have optimized feed system, where the total cow nutritional requirements are met. This criterion is not assumed to be met by current milk production system in Minas Gerais State. The second difference, derived from the first one, is the major feed used. The representative model has Elephant grass, which is the most important grass in the Minas

Gerais State, but it was not necessarily the major one actually used. The term 'representative' will be referred to hereafter as 'model'.

Constrained optimization was used to validate the model by reproducing the resource allocation and technology found on milk farms in Minas Gerais State. The constrained optimization assumed a milk price of US$0.19 and discount rate 6% per year. Table 17 shows the economic performance of the model, which is expected to be similar to that of milk producers in Minas Gerais State and, by extension, similar to that of milk producers in Brazil. This expectation is realistic because the model uses the same herd size, the same breed, the same milk productivity per cow and the same amount of land as is found in Minas Gerais State in typical farms.

The profit is positive only for farm T3, with the investment return rate equal to 1.04%. Farm T1 and T2 have negative investment return rates of –3.91%, and –0.83% respectively. The break-even volume is three times bigger than the daily production in T1, more than two times bigger in T2 and more than one and half times bigger in T3.

TABLE 17

REPRESENTATIVE MODEL RESULTS

System Parameters	Farm T1 (50 liters/day)	Farm T2 (50 <liters/day <2 50)	Farm T3 (> 250 liters/day)
Total capital invested ($)	85,040.57	253,131.67	710,939.60
Net profit ($)	-3,332.40	-2,107.27	7,376.02
Investment return rate (%)	-3.91	-0.83	1.04
Daily Milk produced volume (liters)	55.34	193.51	839.66
Daily milk production Break-even (liters)	187.01	476.72	1437.99

Data generated by the constrained optimization.

Table 17 shows that T1 and T2 farms are losing money. This result is in accordance with the information reported by Jank and Galan (2000). They reported a decrease in the numbers of milk farms delivering milk to the twelfth largest milk processors in Brazil. This decrease was on average equal to 28% from 1996 to 1998. Farm T3 achieves positive return only because returns to the Replacement enterprise are greater than the deficit incurred by the Milk enterprise. In the other two models, the returns to the Replacement enterprises are also positive, but not large enough to make the system profitable.

Changing single parameters, such as increasing the number of cows, or increasing productivity per cow does not improve the profitability of the model farms, because other variables also change so that the constraints are not violated. For example, if the number of cows were increased, which would increase initial capital invested in cows, the amount of capital available for other needs such as feed would be reduced.

Understanding why the profit is low or negative requires an analysis of the performance of the Milk and Replacement enterprises, separately. Table 18 shows the economic performance of the Milk enterprise in the model. The endowment invested in the Milk enterprises in T1, T2 and T3 correspond to 35.4, 30.5, and 32.2 percent of the total investment capacity, respectively, and the returns to investment are negative. Farm T1's return to investment is equal to –23.3%, farm T2's is –19.4% and farm T3's is –13.5% percent. Thus, the models' milk production enterprises are not profitable.

Table 18 indicates that the models' marginal milk cost, the cost of nutrients to produce one more liter of milk, was very low. However, because of fixed costs, the break-even volumes per cow are 13.86, 13.67 and 14.85 liters per day for farms T1, T2 and T3, respectively. However, the current milk production is 4.10, 5.55, and 8.67 liters per day and consequently not enough to pay for the endowment allocated to milk production. Therefore, the system is unbalanced, because productivity per cow, understood as milk production per head, is not sufficient given the endowment allocations.

The information in Table 18 about debt per cow, understood as model average total cost per lactating cow, supports the observation that productivity per cow is too low. The cow debt is US$789.79, US$781.87, and US$851.82, in farms T1, T2 and T3, respectively resulting in a deficit per cow equal to US$552.19, US$460.25 and US$349.39, respectively, per year. Adding more cows with the same productivity increases the loss by adding more deficit cows. This statement reaffirms that productivity per cow is a central point in the milk production system considered here.

TABLE 18

REPRESENTATIVE MODEL - MILK ENTERPRISE

Milk Enterprise (ME)	Farm T1 (50 liters/day)	Farm T2 (50< liters/day <2 50)	Farm T3 (liters/day > 250)
Milk produced (305 days – in liters)	16,878.62	59,023.26	25,6095.99
Revenue from milk ($)	3,206.94	11,214.42	48,658.24
Revenue from beef ($)	422.70	1,091.97	3,032.95
Fixed cost ($)	10,388.26	26,496.84	83,411.78
Variable cost ($)	271.92	765.74	2533.52
Marginal milk cost ($/liter)	0.016	0.013	0.009
Cow break-even production (liters/day)	13.86	13.67	14.85
Total debt per cow ($/year)	789.79	781.87	851.82
Profit per cow ($/year)	-552.19	-460.25	-349.39
Capital invested ($)	30,116.06	77,114.88	228,625.57
Profit ($)	-7,030.54	-14,956.18	-30,804.55
Investment return rate (%/year)	- 23.34	-19.39	-13.47

Data generated by constrained optimization

Notice that the variable cost is very low. This is because the model considers as a variable cost only the cost of nutrients required to produce milk. This is considered in more detail in the feed analyses, discussed below.

Table 19 shows the economic performance of the model's Replacement enterprise. The endowment invested in the Replacement enterprise in farms T1, T2 and T3 corresponds to 25.1, 25.7, and 28.1 percent, respectively, of the total endowment and the returns to investment are positive. Farm T1's return to investment is equal to 16%, farm T2's 20% and farm T3's 19% percent. The average cost, understood as being equal to the average total cost to produce one heifer or steer, is US$269.71, US$242.38 and US$242.38 in farm T1, T2 and T3, respectively. They are equal in T2 and T3 and bigger in T1. The small scale of the T1 farm results in a higher marginal cost and consequently a lower margin per cow sold.

TABLE 19

REPRESENTATIVE MODEL – REPLACEMENT ENTERPRISE

Replacement Enterprise (RE)	Farm T1 (50 liters/day)	Farm T2 50 <liters/day <2 50	Farm T3 (liters/day > 250)
Revenue ($)	14,070.46	44,473.57	133,405.82
Average cost ($/head)	269.71	242.38	242.38
Capital invested ($)	21,347.42	65,049.19	199,430.73
Profit ($)	3,498.19	12,722.47	38,623.13
Investment return rate (%/year)	16	20	19

Data generated by constrained optimization.

The Land enterprise is subsidiary to the Milk and Replacement enterprises and its profit is equal to zero. The model specifies that the Land enterprise produces only the feeds required by the two other enterprises, transferring the total cost to them. The model used this procedure because it is not common in Brazil for milk farms to produce and sell feeds to market.

Continuing the analysis of the representative model, a 50% increase in labor cost was simulated, corresponding to simulation one and an increase in 50% of the total capital invested was simulated, corresponding to simulation two. It should be recalled that the representative model has the same resource allocation and technology as the milk farms in Minas Gerais State. Using the data generated by these simulations, the labor cost elasticity of profit and capital elasticity of profit were calculated as a percentage change in profit divided by the percentage change in labor cost and the amount of capital invested respectively. The results are reported in Table 20.

TABLE 20

REPRESENTATIVE MODEL ELASTICITY

Variables	Farm T1 (50 liters/day)	Farm T2 (50 <liters/day <2 50)	Farm T3 (liters/day > 250)
Labor cost elasticity	-1.17	-4.05	-3.36
Capital elasticity	-0.95	3.32	1.03

Data generated by simulation 1 and 2.

Farm T1 has negative capital elasticity, meaning that with the current resource allocation if more capital were added the farm would be worse off. However, it is the farm that is the least sensitive to labor cost. Its elasticity is larger (negative) than its capital elasticity. This was to be expected since T1 is a small farm, which uses family labor with a resulting lower opportunity cost.

Farm T2 has higher capital and labor cost elasticity than does farm T1. The capital elasticity is very high, which means that it would be profitable to increase the capital investment in the farm. In addition, farm T2 would be a preferential client for government financial programs if they were considered. The elasticity of labor cost is expected to be higher because the middle farms normally hire labor. Since they have less volume and labor productivity than farm T3, they are more sensitive to changes in labor cost than is farm T3.

Farm T3 is also highly sensitive to labor cost but the capital elasticity is low compared to farm T2. It achieves only a 1.03% rate of return on capital (Table 20), for the dollar invested, and under the discount rate assumed, does not have any incentive to grow the capital allocation with the same resource pattern.

The marginal values, reported in Table 21, indicate what the farms should do to improve their profit; and the priority is the same for each all of them. This table shows that the chronic problem in the model*s* is cow productivity. The results indicate that profit would increase by US$701.51, US$1,737.19 and US$4,394.75 for farm sizes T1, T2, and T3 respectively, for every liter added to daily milk production per cow, holding others variables constant.

In addition, notice that investment in mature cows is negative for all model*s*. This means that if the others factors remain constant, adding one more cow will reduce profit. Taken together, the negative coefficients of mature cow investment (herd size) and the high coefficients of cow productivity (daily milk production per cow), for each farm size, suggest that increased cow productivity should be a priority for Brazilian milk production.

TABLE 21

REPRESENTATIVE MODEL MARGINAL VALUES

Marginal values	Farm T1 (50 liters/day)	Farm T2 (50 <liters/day <2 50)	Farm T3 (liters/day > 250)
Mature cow Invest. ($/year)	-0.117	-0.112	-0.100
Lactating cows ($/year)	234.76	308.80	467.26
Pregnant cows ($/year)	33.88	33.88	33.58
Milk prod. cow/day ($/year)	701.51	1,737.19	4,394.75
Heifer second year ($/year)	315.66	315.66	315.66
Steer second year ($/year)	285.66	285.66	-10.95
Capital ($/year)	-0.018	0.028	0.022
Land ($/year)	0.018	-0.028	-0.022

The Table 21 also shows a strong incentive to decrease the calving interval (CI). A reduction in calving interval increases the number of lactating cows without increasing the herd size. The coefficient for lactating cows indicated that increasing the number of lactating cow by one without increasing herd size raises profit by US$234.76, US$308.80, and US$467.26 for farms T1, T2 and T3 respectively. Reductions in the calving interval would require intervention through a change in the technology of the milk production system.

Table 21 suggests that an increase in the number of pregnant cows, related to the fertility rate, is associated with a profit increase of US$33.88, US$33.88 and US$33.58 for T1, T2 and T3 respectively.

Table 21 also indicates that variables from the Replacement enterprise have important marginal values. The Heifer coefficient of marginal values is positive and equal to US$315.66 for each model. In addition, the coefficient for steer has positive values for T1 and T2, but was not relevant for farm T3, implying that the Replacement enterprise is very important for milk production profit. However, the small coefficient of steer for farm T3 indicates that farm T3 would not increase profit substantially by adding more steers.

In brief, milk production systems in Brazil, if the assumed conditions hold, achieve positive profits only for the largest farm size, T3. Farm T3 has negative profit for the Milk enterprise, but a positive value for the Replacement enterprise that is bigger than the negative profit from Milk enterprise. Clearly, the Replacement enterprise plays an important role in the milk production profit. The other two farm sizes also achieve negative profits in the Milk enterprise and positive profit for the Replacement enterprise. Nevertheless, the positive profit of the Replacement enterprise is not large enough to offset the negative profit from the Milk enterprise.

If the conditions implied in the models hold, there are five major conclusions for the current milk production in Minas Gerais State and by extension for the current milk production in Brazil:

(i) Since the models are the average of Brazilian milk production systems, it is expected that: a) farms with productivity per cow close or lower than those assumed in the models are failing or moving to other business; b) for those farms which are above the average but still below the cow productivity break-even, the Replacement enterprise is very important to the overall milk production system profitability; c) when a farm is above the cow productivity break-even, the Milk enterprise is the major contributor to the milk production system profitability;

(ii) Since milk production is a multiple input and multiple output production system the correct allocation of costs can be difficult at the individual farm level, making it difficult to understand the importance of the Milk and Replacement enterprises to system profitability. It is suggested that farms use the approaches and assumptions underlying the conclusions reached in this work.

(iii) It is expected that long run decapitalization if the current milk production system will continue;

(iv) There exists a strong economic incentive for milk farms to migrate to other businesses, mainly to beef production. This is because the Replacement enterprise is similar for beef production and is a major source of profitability. This implies a big structural change in the transition from the milk to the beef industry. Characterizing this transition should be a matter to future research;

(v) There exists a strong economic incentive to adopt technology that is more productive and to adopt better resource allocation.

The fifth conclusion will be the focus of the remainder of this work. It will be examined in light of the hypotheses stated early in this chapter.

Optimizing the Representative Model

The first hypothesis is that the resource allocation under the current technology needs to be shifted. The crossbreed Holstein-Zebu (CrossHZ) represents current technology, with the same cow productivity assumed in the representative model (Table 16). Therefore, a simulation with the current technology and constrained by the investment capacity, has as choice variables amount of land, herd size and feed regime.

The choice variables represent the resource allocation to be optimized. If the optimization process reallocates the resources with the same pattern found in the representative model the hypothesis will be rejected. The rejection of the hypothesis means that the current resource allocation is already optimal and changing resource allocation cannot increase profits.

The conclusion shown in the Table 22 is very clear. Reallocating the current endowment value can substantially increase profits. Therefore, the first hypothesis 'different resource allocation from that currently used can improve profit' was not rejected. This solution is in agreement with the work of Berger et al. (1999).

However, there is no possibility to improve Milk enterprise with the current technology. The results indicate clearly that farm T1, representing small milk producers in Brazil, would go out of business without a change in technology. The optimization shows that farm T1 is better off doing nothing rather than producing under the current technology. This can be deduced from the results in Table 22, because the optimization invested the disposable capital in land, and did not produce anything. Comparing this result with the previous showed (Table 17) that the small farmers achieve better results by doing nothing.

In addition, the results show that farms T2 and T3 are better off stopping the production of milk and migrating to other business. The optimization allocated money to the Replacement enterprise, growing substantially the Replacement enterprise herd size, decreasing significantly the amount of land and finishing milk production. Since the Replacement enterprise, by similarity, can be viewed as the 'beef branch' of the milk production system, the optimization's results suggested that farms T1 and T2 are better of migrating to beef production.

TABLE 22

REPRESENTATIVE MODEL
(Optimizing resource allocation)

Variables	Farm T1 (50 liters/day)	Farm T2 (>50 <2 50 liters/day)	Farm T3 (> 250 liters/day)
Milk Enterprise			
Investment [1]	-	-	-
Profit [1]	-	-	-
Investment return rate [2]	-	-	-
Replacement Enterprise			
Investment [1]	-	246,376.83	694,126.30
Profit [1]	-	7,100.00	15,754.33
Investment return rate [2]	-	2.88	2.27
System			
Mature Cow [3]	-	-	-
Daily Milk Production[4].	4.10	5.55	8.67
Cow BE volume[5]	-	-	-
Growing cows [3]	-	403.96	1091.33
Land [6]	101.15	7.17	19.38
Investment [1]	85,040.57	253,131.67	710,939.60
Profit [1]	-188.43	6,601.35	14,766.67
Investment return rate [2]	-0.2	2.61	2.08

Data generated in simulation three. (1) US$, (2) % per year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (cow/liter/day), (6) ha.

There are three major changes indicated in Table 22, (i) strong reduction in land holdings, (ii) closing the Milk enterprise, and (iii) investment of the endowment value in Replacement enterprise. This solution, if the model assumption hold, unequivocally supports the conclusion that there is a strong economic incentive for milk producers in Brazil to migrate to other business, primarily beef production because of the similarity of them. In addition, the results suggested, for those who want to continue operating milk production, that they should adopt new and more productivity technology for the Milk enterprise.

Since the major concern of this work is milk production, the next step is to test the hypothesis about changing technology and resource allocation. This simulation searched for better technology and resource allocation. The simulation considered six different technologies, each one represented by one breed (Brown Swiss, CrossHZ, Gir, Guzerat, Holstein and Jersey). In addition, the simulation could choose among several variables: primarily herd size, cow productivity (average milk production), disposable land, and feed ration. The constraints imposed are the endowment value, the complete fulfillment of the animal nutritional requirements, and the genetic potential for each breed as an upper bound for cow productivity.

Since the model is non-linear and highly sensitive to starting values, a lower bound for number of mature cows was set equal to 0.01. The optimization process successfully found feasible solutions, and results are reported by farm categories.

Small Farm Results

The first results, corresponding to simulation four, assume a scenario where the inflation rate is 4.5%, the discount rate is 6%, and milk price is US$0.19 per liter. In order to verify the hypothesis 'changing technology and resource allocation can improve profit' the simulation considered the following technology improvements.

(i) Test six breeds adopting as genetic potential for milk production, for each breed, the productivity per cow currently found in Brazil and reported by Martinez (2000).

This technology, considered available for farmers, implies increasing the upper bound of the genetic potential from 4.1 to 10.12 liters per day, considering for example CrossHZ. See the Appendix C to more detail.

(ii) Reducing to 50% the difference between the current and 'ideal' calving intervals. The 'ideal' calving interval was assumed equal to 12 months.

(iii) Reducing feed cost by 25%.

The simulation results, reported in Table 23, supported the hypothesis.

TABLE 23

OPTIMIZED REPRESENTATIVE MODEL SMALL FARM
(Milk price equal to US$0.19 and available technology)

Variables	Brown-Swiss	CrossHZ	Gir	Guzerat	Holstein	Jersey
Milk Enterprise						
Investment [1]	74,098.03	74,638.60	-	-	75,448.18	74,627.62
Profit [1]	-6,399.60	7,385.86	-	-	1,355.04	-6,730.62
Investment return rate [2]	-9.00	-10.00	-	-	2.00	-9.00
Replacement Enterprise						
Investment [1]	5,455.42	5,892.69	65,445.18	-	5,243.82	5,714.44
Profit [1]	11,265.60	11,138.25	200.93	-	12,440.33	11,075.86
Investment return rate [2]	1.07	89.00	0.3	-	137.00	94.00
System						
Mature Cow [3]	32.60	34.93	-	-	33.91	33.70
Daily Milk Production.	13.75	10.12	-	-	17.19	12.19
Cow BE volume[5]	18.45	14.69	-	-	17.17	16.16
Growing cows [3]	7.17	7.84	100.02	-	6.84	7.57
Land [6]	6.66	5.47	22.75	101.16	5.28	5.70
Investment [1]	85,040.57	85,040.57	85,040.57	85,040.57	85,040.57	85,040.57
Profit [2]	4,590.56	3,539.99	93.14	-	13,014.50	4,099.28
Investment return rate [3]	5.00	4.00	0.11	-	15.00	5.00

(1)US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (liter/day), (6) ha.

Breeds achieved positive values for the system as a whole, except Guzerat. However, four of them, Brown Swiss, CrossHZ, Gir, and Jersey, did not achieve a positive profit in the Milk enterprise, and Guzerat, under the available technology is so poor that the farmer is better off doing nothing. In addition, an exceptional condition was admitted for all breeds – decrease in feed costs and calving intervals – and even under this exceptional condition, they still did not achieve positive profit. This means that milk production with these technologies is not profitable for farmers with an investment capacity equal to that of farm T1.

Notice that all breeds have smaller cow productivity than the cow productivity break-even except Holstein. Consequently, they have high marginal prices, which are equal to US$1,229.82, US$1,397.56, US$0.32, US$0.35, US$1,150.18 US$1,460.25 for Brown Swiss, CrossHZ, Gir, Guzerat, Holstein and Jersey, respectively. Therefore, there is a substantial economic incentive to increase the cow productivity in these breeds.

Gir and Guzerat have a marginal value, which is close to zero because the optimization did not allocate capital to milk production in these breeds. Guzerat is not indicated under the T1 farm investment level. However, Gir could be used in the Replacement enterprise. In addition, Gir is the most important Zebu breed used to create a crossbreed with Holstein, producing the CrossHZ breed. Therefore, its production should be considered for this purpose too.

In addition, sensitivity analysis was conducted for Holstein regarding the risk represented by the parameter mortality rate. The risk elasticities calculated are equal to –0.104 for herd size, and -0.0027 for Milk enterprise investment, showing an inelastic investment pattern and –0.011 for profit. The risk elasticity of profit is very low and it did not support the idea that risk from mortality rate in Holstein could be economically significant in farm T1 investment capacity.

In brief, under the currently average cow productivity found in Brazil, only Holstein breed achieved positive profit and it is economical advisable to farm T1 investment capacity.

The next results, corresponding to simulation five, assume a scenario where the inflation rate is 4.5%, the discount rate is 6%, and milk price is US$0.19 per liter. In order to verify the hypothesis 'changing technology and resource allocation can improve profit' the simulation considered the following technology improvements.

(i) Test six breeds increasing average milk cow productivity, for each breed, by half the difference between their genetic potential for milk production, reported in the National Dairy Technical Records Archive and current average milk production found in Brazil and reported by Martinez (2000).

This technological change implies increasing the upper bound of the genetic potential from 10.12 to 24.73 liters per day, considering for example CrossHZ. See the Appendix C for more detail.

(ii) Reducing to 50% the difference between current and 'ideal' calving interval. The 'ideal' calving interval was assumed equal to 12 months.

(iii) Reducing feed cost by 25%.

The simulation results, reported in Table 24, support the hypothesis.

TABLE 24

OPTIMIZED REPRESENTATIVE MODEL SMALL FARM
(Milk price equal to US$0.19)

Variables	Brown-Swiss	CrossHZ	Gir	Guzerat	Holstein	Jersey
Milk Enterprise						
Investment [1]	79,262.60	78,859.34	67,354.72	78,754.30	79,557.67	75,835.32
Profit [1]	7,019.24	6,166.95	-2,942.06	-5,670.56	15,717.88	-2,320.84
Investment return rate [2]	8.85	7.82	-4.34	-7.20	19.76	-3.06
Replacement Enterp.						
Investment [1]	4,616.97	5,089.74	4,679.93	5,514.64	4,361.56	5,498.64
Profit [1]	14,639.28	14,036.48	11,743.96	12,775.26	15,545.39	11,901.53
Investment return rate [2]	217	176	151	132	256	116
System						
Mature Cow [3]	26.70	29.40	26.57	33.36	24.38	32.21
Daily Milk Production[4].	32.38	24.73	20.66	16.13	40.25	15.93
Cow BE volume[5]	28.29	21.59	23.83	20.25	29.42	17.72
Growing cows [3]	5.87	6.60	5.97	7.26	5.48	7.24
Land [6]	1.41	1.32	15.78	0.94	1.36	4.50
Investment [1]	85,040.57	85,040.57	85,040.57	85,040.57	85,040.57	85,040.57
Profit [2]	20,432.57	19,059.84	8,303.67	6,702.55	29,493.64	9,038.39
Investment return rate [3]	24.02	22.41	9.76	7.88	34.68	10.63

(1) US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (cow/liter/day), (6) ha.

Notice that all breeds achieved positive values for the system as a whole. However, three of them, Gir, Guzerat and Jersey, did not achieve a positive profit in the Milk enterprise. This means that milk production, with these technologies, is not profitable for farmers with investment capacity equal to that of farm T1. Since this optimization considers an exceptional condition - high technological changes - and, even under this exceptional condition they did not achieve positive profits, the possibility that these breeds can produce positive profits with farm T1's investment capacity is zero. The major problem faced by these breeds is that productivity per cow is lower than the cow break-even volume. Thus, there is no possible resource allocation, which can achieve positive profit using these breeds.

A useful result of this analysis is that it suggests that an indicator for evaluating a given milk production system is the break-even volume of daily per cow milk production. In addition, the break-even volume could be also a cow-culling criterion, in which cows achieving daily production below the break-even volume, for a given system, should be considered candidates for culling. Dr. Eliseu Alves (EMBRAPA-SEDE) suggested the use of the break-even volume to cull animals, and its usefulness is confirmed by these results.

By comparing the representative model (Tables 17, 18 and 19), with the results of the optimized representative model (Table 24), there are three major changes indicating sources of inefficiency in the milk production system in Brazil.

(i) There is too much land allocated to milk production.

Notice that all breeds use less land in the optimized model than the representative model, including here the CrossHZ. The reduction is substantial.

(ii) There is too little cow investment in the milk production.

(iii) There is too little cow productivity.

In addition to these three changes, the hypothesis that 'changing technologies and changing resource allocation can improve profitability' cannot be rejected.

By correcting these inefficiencies, the optimization process found a profitable milk production systems for farm T1. Brown-Swiss, CrossHZ and Holstein achieve positive profits in the Milk enterprise with a rate of return of investment equal to 9%, 8% and 20%, respectively. Under the model assumptions, these three breeds achieve positive profits in milk production even under farm T1's investment constraint, although Holstein is clearly the superior breed. The results also indicate that if farms T1 increase the productivity per cows of the current breed (CrossHZ) and reallocates land it could continue in the milk production business. However, it will be even better off changing also the breed.

The next simulation considers the effect of decreasing milk prices. This simulation assumes that milk price decline to US$0.15, corresponding to simulation six. The results are shown in Table 25.

The breeds that were profitable under higher milk price (milk price equal to US$0.19) continue to be profitable when milk price decreases to US$0.15 per liter. The major changes which occur as a result of the milk price decrease are:

(i) Optimal herd size increases since cow productivity is in the upper bound limit.

The increase in herd size should be achieved by increasing the number of mature cows in the herd. This conclusion is in accordance with Weersink and Tauer (1991) and with El-Osta and Johnson (1998). However Ramsden et al. (1999) reported that there is some incentive to reduce productivity per cow when the milk price decrease, a result which was not observed in this work.

(ii) Increase the investment in the Replacement enterprise when CrossHZ animals are used.

These conclusions confirm results reported earlier indicating the importance of the Replacement enterprise to milk production in farms at T1 level, and explain why the CrossHZ is so popular. In addition, the two other breeds are inelastic with regard to changing investment patterns, meaning that for them to continue producing milk is better than moving investment to the Replacement enterprise. In addition, the rigidity of these two breeds reflects their high milk production capacity and their ability to be profitable in the Milk enterprise under scenarios of decreasing milk price.

(iii) Increase the amount of investment in the Land enterprise.

The third conclusion is very important because it implies that under decreasing milk prices there is a tendency to increase the importance of the Land enterprise and consequently to increase the importance of the grazing system. This conclusion is consistent with the results of Ramsden et al. (1999), Tozer and Huffaker (1999), Berger et al. (1999), Brockington et al. (1992). In reality, the estimated milk price elasticity of production factors and profit reinforces the negative relationship between milk price and the amount of land used.

Increase in land use is a clear tendency, with the CrossHZ breed going more 'quickly' to a pasture base, than the others. In addition, profit with the CrossHZ breed is more negatively elastic with respect to changes in milk price. The CrossHZ breed system incorporates a change in investment pattern from Milk to Replacement enterprise when the prices decrease. This 'flexibility' may come from its characteristics of a dual – purpose cow with good capacity for producing milk and, at same time producing meat. This explains why they are so popular in Brazil that has a history of large milk price fluctuations. Therefore, farmers can exploit its capacity to produce milk when the milk price appears attractive and its capacity to produce meat when the beef price is high. This is in accord with the findings of Brandao (1999). In addition, these results suggest that future research is required to verify if CrossHZ receives a better beef price than the other breeds, because of its dual – purpose characteristics.

TABLE 25

OPTIMIZED REPRESENTATIVE MODEL SMALL FARM
(Milk price equal to US$0.15)

Variables	Brown-Swiss	CrossHZ	Holstein
Milk Enterprise			
Investment [1]	79,169.16	78,436.39	79,422.71
Profit [1]	6,500.37	6,832.68	12,066.35
Investment return rate [2]	8.21	8.71	15.19
Replacement Enterprise			
Investment [1]	4,564.16	5,207.14	4,410.08
Profit [1]	11,816.83	7,211.42	10,106.28
Investment return rate [2]	158.90	38.49	129.16
System			
Mature Cow [3]	27.97	32.09	26.26
Daily Milk Production[4].	32.38	24.73	40.25
Cow BE volume[5]	28.48	20.67	30.79
Land [6]	1.59	1.70	1.47
Investment [1]	85,040.57	85,040.57	85,040.57
Profit [2]	17,280.38	13,249.15	20,917.57
Investment return rate [3]	20.32	15.57	24.59

(1) US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (cow/liter/day), (6) ha.

TABLE 26

OPTIMIZED REPRESENTATIVE MODEL SMALL FARM
MILK PRICE ELASTICITY OF PRODUCTION FACTORS AND PROFIT

Variables	Brown-Swiss	CrossHZ	Holstein
Mature cows	0.23	0.44	0.37
Land Investment	0.60	1.36	0.38
Profit	-0.73	-1.45	-1.38
Milk enterp. Investment	-0.0056	-0.0254	-0.0081
Rep. Enterp. Investment	-0.0543	0.1096	0.053

The next simulation considers milk prices equal to US$0.15/liter and an increase in the interest rate from 6 to 12% percent. This simulation is concerned with increases in the inflation rate reflecting an increase in interest rate. It corresponds to simulation six and its results are shown in the Table 27.

The results showed no major change in the investment pattern. The only effect is a profit decrease due to an increase in the discount rate. In addition, the elasticity reported in the Table 28, confirms the current investment pattern and the optimal resource allocation. Under increasing inflation, the representative model (T1) is inelastic regarding the investment pattern, even including the breed CrossHZ.

TABLE 27

OPTIMIZED REPRESENTATIVE MODEL SMALL FARM
(Milk price equal to US$0.15 and discount rate equal to 12%)

Variables	Brown-Swiss	CrossHZ	Holstein
Milk Enterprise			
Investment [1]	78,705.49	78.268.95	79,271.04
Profit [1]	5,481.79	6,566.90	11,772.60
Investment return rate [2]	6.96	8.39	14.85
Replacement Enterprise			
Investment [1]	4,862.55	5,399.16	4,579.20
Profit [1]	8,370.58	7,050.47	9,932.37
Investment return rate [2]	72.14	30.58	116.90
System			
Mature Cow [3]	28.42	31.53	25.88
Daily Milk Production[4].	32.38	24.73	40.25
Cow BE volume[5]	28.94	20.78	30.90
Land [6]	1.79	1.67	1.44
Investment [1]	85,040.57	85,040.57	85,040.57
Profit [1]	12,368.18	12,158.37	19,379.44
Investment return rate [2]	14.54	14.29	22.78

(1)US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (liter/day), (6) ha.

TABLE 28

OPTIMIZED REPRESENTATIVE MODEL SMALL FARM
DISCOUNT RATE ELASTICITY OF PRODUCTION FACTORS AND PROFIT

Variables	Brown-Swiss	CrossHZ	Holstein
Mature cows	0.016	-0.017	-0.014
Land Investment	0.125	-0.02	-0.02
Profit	-0.28	-0.08	-0.07
Milk enterp. Investment	-0.005	-0.002	-0.001
Rep. enterp. Investment	0.065	0.037	0.038

Middle Farm Results

The same procedure used above was applied to Farm T2. Remember that the first simulation assumed a scenario where the inflation is 4.5% and the discount rate is 6%. In addition, this scenario assumes a milk price equal to US$0.19. This optimization assumes that the farmer can improve technology. The improvements adopted are equal to the farm T1. The results for this simulation are shown in the Table 29.

TABLE 29

OPTIMIZED REPRESENTATIVE MODEL MIDDLE FARM
(Milk price equal to US$0.19 and available technology)

Variables	Brown-Swiss	CrossHZ	Gir	Guzerat	Holstein	Jersey
Milk Enterprise						
Investment [1]	221,793.88	223,424.05	-	-	225,865.46	223,390.92
Profit [1]	-19,099.73	-22,073.96	-	-	4,285.70	-20,097.98
Investment return rate [2]	-9.00	-10.00	-	-	2.00	-9.00
Replacement Enterprise						
Investment [1]	14,790.46	16,109.14	195,736.38	-	14,152.36	15,571.58
Profit [1]	34,172.68	33,788.64	799.16	-	37,715.27	33,600.48
Investment return rate [2]	131.00	110.00	0.40	-	166	116
System						
Mature Cow [3]	98.30	105.33	-	-	91.85	101.63
Daily Milk Production[4].	13.75	10.12	-	-	19.21	12.19
Cow BE volume[5]	18.41	14.65	-	-	19.08	16.12
Growing cows [3]	21.62	23.66	301.68	-	20.63	22.83
Land [6]	20.08	16.50	68.61	305.11	15.91	17.19
Investment [1]	253,131.67	253,131.67	253,131.67	253,131.67	253,131.67	253,131.67
Profit [2]	14,219.76	11,051.58	657.51	-	39,623.55	12,738.21
Investment return rate[2]	6.00	4.00	0.250	--	16.00	5.00

(1)US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (cow/liter/day), (6) ha.

Most breeds achieved positive values for the system as a whole, except for the Guzerat. However, four of them, Brown-Swiss, CrossHZ, Gir, and Jersey, did not achieve a positive profit in the Milk enterprise, and Guzerat, under the available technology is so negative that the farmer is better off doing nothing. In addition, an exceptional condition was admitted – a decrease in feed costs and calving intervals was allowed – and under this exceptional condition, the farms still did not achieve a positive profit. This means that milk production with these technologies is not profitable for farmers with investment capacity equal to that of farm T2.

Notice that all breeds have smaller cow productivity than cow productivity break-even except Holstein. Consequently, they have a high cow productivity marginal prices, which are equal to US$3,708.74, US$4,214.59, US$0.32, US$0.35, US$3,468.56, US$4,403.63 for Brown Swiss, CrossHZ, Gir, Guzerat, Holstein and Jersey, respectively. Therefore, there is an economic incentive to increase the cow productivity in these breeds.

Gir and Guzerat have a marginal value close to zero because the optimization did not allocate capital to milk production in these breeds. Guzerat is not indicated under T2 farm investment level either. Gir could, however, be used in the Replacement enterprise. In addition, Gir is the most important Zebu breed used to create a crossbreed with Holstein, producing the CrossHZ breed. Therefore, its production should be considered for this purpose too.

In addition, a sensitivity analysis was conducted for the Holstein regarding risk using mortality rate parameter. The elasticities calculated are similar to those for the T1 farm. However, the risk elasticity of herd size became more inelastic and equal to -0.0028. The risk elasticity of profit is very low and it did not support the idea that risk from mortality rate in Holstein could be economically significant to the farm T2 investment capacity either.

In brief, for the current average cow productivity found in Brazil, only the Holstein breed achieved a positive profit and it is economically advisable to farm T2 investment capacity using this breed.

The same procedure regarding an increase in technology used in T1 was developed for the Farm T2, corresponding to the fifth simulation. Remember that this simulation assumes a scenario where the inflation is 4.5% and the discount rate is 6%. In addition, this scenario assumes a milk price equal to US$0.19. The optimization assumes that the farmer can improve technology. The improvements adopted are equal to those for the farm T1 for new technology. The results for this simulation are shown in the Table 30.

Notice that all breeds had positive values for the system as a whole. However, the same results found in T1 also were found here, where Gir, Guzerat and Jersey did not generate a positive profit for the Milk enterprise. They improved by 1% compared with their performance under T1 investment level, but still remained negative. This means that they are not feasible for milk production for a farm of T2 investment capacity either. In addition, for the same reasons explained in the case of T1, the possibility of these breeds to generate a positive profit, under the T2 farm investment capacity, and under the assumptions assumed in the model, is zero. The major problem faced by these breeds is the unbalanced system because the productivity per cow is lower than the cow break-even volume required by the optimized system.

TABLE 30

OPTIMIZED REPRESENTATIVE MODEL MIDDLE FARM
(Milk price equal to US$0.19)

Variables	Brown-Swiss	CrossHZ	Gir	Guzerat	Holstein	Jersey
Milk Enterprise						
Investment [1]	238,117.98	236,655.24	201,386.70	236,375.92	238,922.96	227,416.95
Profit [1]	24,178.09	21,830.30	-6,351.29	-13,559.37	50,462.83	-3,941.91
Investment return rate [2]	10.00	9.00	-3.00	-6.00	21.00	-2.00
Replacement Enterprise						
Investment [1]	11,761.60	13,129.61	11,929.47	14,384.60	11,009.19	14,330.96
Profit [1]	45,544.26	43,854.09	36,706.65	40,143.66	48,282.83	37,427.18
Investment return rate [2]	287	234	208	179	339	161
System						
Mature Cow [3]	81.83	90.13	81.34	102.51	74.60	93.93
Daily Milk Production[4].	32.38	24.73	20.66	16.13	40.25	15.93
Cow BE volume[5]	27.65	20.98	23.15	19.50	28.84	17.16
Growing cows [3]	17.99	20.24	18.27	22.31	16.76	22.22
Land [6]	3.95	4.06	48.31	2.88	3.88	13.81
Investment [1]	253,131.67	253.131.67	253.131.67	253.131.67	253.131.67	253.131.67
Profit [2]	65,775.79	61,966.40	28,637.13	25,079.52	93,156.26	31,589.87
Investment return rate[2]	26.00	24.00	11.00	10.00	37.00	12.00

(1)US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (cow/liter/day), (6) ha.

The difference between T1 and T2 is only the amount invested, confirming the idea that increasing the herd size with an unbalanced system cannot generate a positive profit. Here, the methodology for evaluating a given milk production system, or a discharge cow criterion by considering the break-even volume as a reference analyze, is also valid.

By comparing the representative model with the results of the optimized model, three major changes indicated the sources of unbalances (inefficiency) in the milk production system in Brazil.

(i) There is too much land allocated to milk production.

Notice that all breeds use less land in the optimized model than the model representative, including here the CrossHZ. The reduction is incredibly large.

(ii) There is too little cow investment in the milk production.

The herd size was increased in all breeds including the CrossHZ. The herd size in the optimized model is more than double the representative model.

(iii) There is too little cow productivity.

The cow productivity achieves its upper bound in the optimized model for all breeds including the CrossHZ.

By correcting the resource allocation the optimization process succeeded in finding a profitable milk production system for farm T2 where Brown Swiss, CrossHZ and Holstein have positive profits for the Milk enterprise with investment return rates equal to 10%, 9% and 21% respectively. It shows that under the model assumptions the cited three breeds are feasible for producing milk under the farm T2 investment constraint and that the Holstein is the best.

Comparing the performance of the breeds, there is a 1% growth in the investment return rate from farm T1 to T2. This implies, considering the breeds with positive profit, a capital elasticity of investment return rate equal to Brown Swiss 0.056, CrossHZ 0.063 and Holstein 0.025. These results mean that there is a slight positive or constant return to scale, which agrees with the information found in the literature. This information was confirmed using Holstein as an example. The ratio between investment growth (2.97) and the profit growth (3.15), from T1 to T2 is 1.058, confirming the constant return to scale.

The next simulation for T2 considered decreasing milk prices and the breeds that have gotten positive profit under the first simulation. This simulation assumed a milk price equal to US$0.15 and the results are shown in the Table 31.

The breeds that were profitable under first simulation (where milk price is equal to US$0.19), continue to be profitable under a milk price decrease to US$0.15 per liter. The major changes implied from the decreasing in milk price are:

(i) Optimal herd size increases since cow productivity is an upper bound limit.

The increase in the herd is done by increase the number of mature cows. This conclusion is in accordance with the conclusions of Weersink and Tauer (1991), El-Osta and Johnson (1998). However Ramsden et al. (1999) reported that there is some incentive to reduce the productivity per cow when the milk price goes down, which was not perceived in the T2 farm level simulation either.

(ii) Increase the investment in Replacement enterprise.

The relevance of the Replacement enterprise for farms of size T2 is not the same as for the T1 farms. Notice that the change in Replacement investment is quite large compared with T1, especially for CrossHZ. A large change also occurs with Holstein and Brown Swiss that were rigid in T1 but now accept change in the investment pattern from Milk to Replacement enterprise when milk price goes down. In addition, the CrossHZ is more elastic, with regard to a change in the investment pattern from Milk to Replacement enterprise in T2, than in T1.

(iii) Increase the investment in Land enterprise.

This set of conclusions is very important because it implies that under conditions of decreasing milk price, T2 has a tendency to increase the importance of the

Replacement and Land enterprises. Again, the 'flexibility' of the CrossHZ, a dual – purpose cow appears to be a good explanation for its popularity in Brazil.

It is important to realize that the basic feed remains constant, and the milk production is based on Elephant grass meaning that like T1, T2 also has an incentive to base milk production in pasture. Holstein does not change the feed regime due to a decrease in milk price, however Brown Swiss and the CrossHZ do change some feeds. They have 'Brachiaria Brizantha' in their feed regime, considered to be middle to low quality feed. When the prices decreased they eliminated it and increased the amount of other feeds such as Elephant grass, considered to be superior grass. Therefore, there is no positive relation between lower milk prices and poor feed, which is in accordance with Tozer and Huffaker (1999), Ramsden et al. (1999), McCall and Clark (1999), Brockington et al. (1992). This finding reinforces the management philosophy adopted in this work about the complete fulfillment of the animal requirements. The fulfillment should be under smaller cost without any pre-conception about the link between small milk prices and lower feed quality.

The milk price elasticity of land reinforces the negative relationship between milk price and land investment discussed before. An increase in land investment is a clear tendency and Brown Swiss goes more 'quickly' to pasture base, than the others.

The Holstein is more stable because it has a smaller negative milk price elasticity of profit. All breeds are inelastic regarding the change in the amount invested in the Milk Enterprise. However, they are less inelastic with regard to the investment in the Replacement enterprise, which characterizes the difference between T1 and T2. This implies that T2 has an incentive to increase the Replacement enterprise investments when the milk price goes down in all three breeds with CrossHZ being more elastic than the others.

TABLE 31

OPTIMIZED REPRESENTATIVE MODEL MIDDLE FARM
(Milk price equal to US$0.15)

Variables	Brown-Swiss	CrossHZ	Holstein
Milk Enterprise			
Investment [1]	236,152.24	234,879.88	237,854.04
Profit [1]	19,627.58	23,282.16	38,615.87
Investment return rate [2]	8.31	9.91	16.24
Replacement Enterprise			
Investment [1]	12,467.03	14,038.32	11,635.08
Profit [1]	26,432.07	22,504.88	31,134.04
Investment return rate [2]	112.02	60.31	167.59
System			
Mature Cow [3]	87.10	96.79	79.19
Daily Milk Production[4].	32.38	27.73	40.25
Cow BE volume[5]	28.13	20.01	30.14
Land [6]	5.48	5.11	4.42
Investment [1]	253,131.67	253,131.67	253,131.67
Profit [2]	43,452.50	43,195.32	65,801.80
Investment return rate [2]	17.17	17.06	25.99

(1)US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (cow/liter/day), (6) ha.

TABLE 32

OPTIMIZED REPRESENTATIVE MODEL MIDDLE FARM
MILK PRICE ELASTICITY OF PRODUCTION FACTORS AND PROFIT

Variables	Brown-Swiss	CrossHZ	Holstein
Mature cows	0.306	0.351	0.292
Land Investment	1.84	1.23	0.66
Profit	-1.61	-1.43	-1.39
Milk enterp. Investment	-0.039	-0.036	-0.022
Rep. Enterp. Investment	0.285	0.329	0.270

The next simulation considers milk prices equal to fifteen cents and an increase in the interest rate from six to twelve percent. This simulation concerns increases in the inflation rate reflecting changes in the discount rate.

The results are shown in Table 33, and there is no major change in the investment pattern. The only effect is the decrease in profit due to the increase in the discount rate. In addition, the elasticity reported in the Table 34, confirms the current investment pattern and the rigidity of the optimal model. The expressive difference from a decrease in milk price to an increase in inflation rate is the inelastic pattern of the Replacement enterprise investment, where the Holstein is perfectly inelastic.

In brief, analyzing the information in Table 33 and 34 the T2 farm has similar results to those for T1. T2 farms can continue in milk production business using CrossHZ, if they increase the productivity per cow and, at the same time, better organize the allocation of resources. However, with the same amount of endowment value invested the Holstein performance generates more than 50% of the profit. However, CrossHZ has more flexibility under inflation and decreases in milk price, enabling a flexible solution for those who expect such scenarios and want to exploit the negative relationship between milk and beef price. In addition, the investment in land is negatively related to the inflation rate. When the inflation rate goes up the investment in land is inelastic but with a negative sign.

TABLE 33

OPTIMIZED REPRESENTATIVE MODEL MIDDLE FARM
(Milk price US$0.15 and discount rate 12%)

Variables	Brown-Swiss	CrossHZ	Holstein
Milk Enterprise			
Investment [1]	235,688.44	234,371.98	237,854.04
Profit [1]	16,730.61	20,002.96	36,615.87
Investment return rate [2]	7.10	8.53	15.39
Replacement Enterprise			
Investment [1]	13,002.56	14,620.80	11,635.08
Profit [1]	25,442.25	21,461.25	31,134.04
Investment return rate [2]	95.67	46.79	167.58
System			
Mature Cow [3]	85.72	95.08	79.19
Daily Milk Production[4].	32.38	24.73	40.25
Cow BE volume[5]	28.88	20.73	29.74
Land [6]	5.39	5.02	4.42
Investment [1]	253,131.67	253,131.67	253,131.67
Profit [2]	37,654.33	37,021.60	62,276.69
Investment return rate [2]	14.88	14.63	24.60

(1)US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (cow/liter/day), (6) ha.

TABLE 34

OPTIMIZED REPRESENTATIVE MODEL MIDDLE FARM
DISCOUNT RATE ELASTICITY OF PRODUCTION FACTOR AND PROFIT

Variables	Brown-Swiss	CrossHZ	Holstein
Mature cows	-0.016	-0.017	0
Land Investment	-0.125	-0.02	0
Profit	-0.28	-0.08	-0.054
Milk enterprise Investment	-0.005	-0.002	0
Rep. enterp. investment	0.065	0.037	0

Big Farm Results

Equivalent simulations were conducted for the T3 farm level. The first simulation assumes a scenario where the inflation is 4.5%, the discount rate is 6% and the milk price is US$0.19. The optimization assumes that the farmer can improve technology. The improvements adopted are equal to those for farms T1 and T2. The results for this simulation are shown in the Table 35.

TABLE 35

OPTIMIZED REPRESENTATIVE MODEL BIG FARM
(Milk price US$0.19 and available technology)

Variables	Brown-Swiss	CrossHZ	Gir	Guzerat	Holstein	Jersey
Milk Enterprise						
Investment [1]	624,053.88	628,651.68	-	-	635,537.52	628,558.24
Profit [1]	-53,689.41	62,078.04	-	-	12,667.57	-56,504.91
Invest. Return rate[2]	-9.00	-10.00	-	-	2.00	-9.00
Replacement Ent.						
Investment [1]	40,215.11	43,934.36	550,593.63	-	38,415.40	42,418.19
Profit [1]	96,561.71	95,478.55	2,428.50	-	106,553.34	94,947.87
Invest. Return rate[2]	140	117	0.40	-	177	124
System						
Mature Cow [3]	277.26	297.08	-	-	259.05	286.64
Daily Milk Production[4].	13.75	10.12	-	-	19.21	12.19
Cow BE volume[5]	18.40	14.64	-	-	19.07	16.11
Growing cows [3]	60.97	66.72	850.92	-	58.18	64.38
Land [6]	56.63	46.54	193.53	860.58	44.88	48.49
Investment [1]	710,939.60	710,939.60	710,939.60	710,939.60	710,939.60	710,939.60
Profit [2]	40,445.56	31,509.91	2,194,62	-	16.00	36,266.94
Invest. Return rate [2]	6.00	4.00	0.30			5.00

(1)US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even production (cow/liter/day), (6) ha.

Notice that, again all breeds have smaller cow productivity than cow productivity break-even except Holstein. Consequently, they have a high cow productivity marginal prices, which are equal to US$10,460.24, US$11,886.95, US$0.32, US$0.35, US$9,782.84 US$12,420.13 for Brown Swiss, CrossHZ, Gir, Guzerat, Holstein and Jersey, respectively. The small marginal price for Gir and Guzerat occurred because they did not produce milk.

In addition, all breeds had positive values for the system as a whole, except for Guzerat where the farmer is better off doing nothing. However, the Brown Swiss, CrossHZ, Gir, and Jersey, did not generate positive profits for the Milk Enterprise. This means that they are not useful for milk production for farms T1, T2 and T3 investment capacity, considering the available technology. The major problem faced by these breeds is the unbalanced system because the productivity per cow is lower than the cow break-even volume. With this situation, there is no possible resource allocation to make positive profit using these breeds. Increasing the investment in this unbalanced system does not solve the problem.

In addition, sensitivity analysis was conducted for Holstein regarding risk using the mortality rate parameter. The elasticities calculated are exactly the same as those for the T2 farm. The risk elasticity of profit is very low and does not support the idea that risk from mortality rate in Holstein could be economically significant in the farm T3 investment capacity. Therefore, the only breed economically advisable under the available technology is the Holstein breed.

The next simulation assumes a scenario where the inflation is 4.5%, the discount rate is 6% and milk price is US$0.19. The optimization assumes that the farmer can improve technology. The improvements adopted are the same as those for farms T1 and T2. The results for this simulation are shown in the Table 36.

Notice that all breeds generated positive values for the system as a whole. However, the Gir, Guzerat and Jersey, did not make a positive profit for the Milk enterprise. In addition, the negative investment rate did not change from T2 to T3 as they did from T1 to T2. This means that they are not feasible for milk production for farms of

T1, T2 and T3 investment capacity. Since this optimization also considers the exceptional condition – high technological changes – and under this exceptionality, they did not succeed positive profit, the possibility of these breeds for making positive profit, under the T1, T2 and T3 farm investment capacity, and under the assumptions assumed in the model, is zero. The major problem faced by these breeds is the unbalanced system because the productivity per cow is lower than the cow break-even volume. With this situation, there is no possible resource allocation to make a positive profit using these breeds. An increase in the investment in this unbalanced system does not solve the problem. These results cast doubt on the capacity of these breeds to be profitable in milk production under Brazilian conditions if the assumptions in the representative model hold.

TABLE 36

OPTIMIZED REPRESENTATIVE MODEL BIG FARM
(Milk price US$0.19)

Variables	Brown-Swiss	CrossHZ	Gir	Guzerat	Holstein	Jersey
Milk Enterprise						
Investment [1]	669,149.23	664,947.33	566,642.24	664,082.77	670,842.15	639,132.62
Profit [1]	66,884.27	60,188.88	-18,290.65	-40,081.31	140,539.31	-10,201.66
Invest. return rate [2]	10	9.05	-3.23	-6.04	20.95	-1.60
Replacement Enterprise						
Investment [1]	32,716.85	36,665.03	33,207.07	40,258.97	30,522.86	40,118.47
Profit [1]	127,083.28	122,207.67	102,425.55	111,648.29	134,735.36	104,182.68
Invest. return rate [2]	288.43	233.31	208.45	177.33	341.42	159.69
System						
Mature Cow [3]	228.30	251.19	226.96	251.14	208.14	275.40
Daily Milk Production[4].	32.38	24.73	20.66	13.04	40.25	15.93
Cow BE volume[5]	27.70	21.03	23.20	16.14	28.86	17.11
Growing cows [3]	5.87	6.60	5.97	7.26	5.48	7.24
Land [6]	11.01	11.32	134.79	8.01	11.62	38.45
Investment [1]	710,939.60	710,939.60	710,939.60	710,939.60	710,939.60	710,939.60
Profit [2]	182,988.22	172,072.19	79,372.53	67,516.01	259,693.04	88,661.32
Invest. return rate [2]	25.74	24.20	11.16	9.50	36.53	12.47

(1)US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (liter/day), (6) ha.

By comparing the representative model with the results of the optimized model, three major changes indicate the sources of unbalances (inefficiency) in the milk production system in Brazil. They are the same as those for the other farms categories, excess of land, small herd size and small productivity per cow.

Analyzing the T3 model, regarding return to scale, the constant return to scale was confirmed. The investment capacity growth from US$253,131.67 (T2) to US$710,0939.60 (T3) increased 2.977 times. The return to scale is equal to 1.01. The constant returns-to-scale is expected if the production function is optimal. With an optimal production function, a doubling of the quantity of inputs, should result in a doubling of the outputs. This observed result is a good indication of the quality of the optimization process.

The following simulation considers decreasing milk prices and considers those breeds that have obtained positive profit under the first simulation. This simulation assumes a price equal to US$0.15 and the results are shown in the Table 37.

The breeds that were profitable under first simulation continue to be profitable under a milk price decrease to US$0.15 per liter. The major changes implied from the decreasing in milk price, are similar to those observed for T1 and T2.

The milk price elasticity of production factors, estimated using data from the model under nineteen and fifteen cents per liter reinforce, once more, the negative relation between milk price and land investment. This does not depend on the scale of production.

Increase in land investment is a clear tendency and Brown Swiss goes more 'quickly' to pasture base, than the others. Holstein is more stable because it has a smaller negative milk price elasticity of profit. All breeds continue to be inelastic with respect to changes in the amount invested in the Milk enterprise and all breeds show an elastic pattern with regard to the Replacement enterprise investment when the milk price goes down.

TABLE 37

OPTIMIZED REPRESENTATIVE MODEL BIG FARM
(Milk price US$0.15)

Variables	Brown-Swiss	CrossHZ	Holstein
Milk Enterprise			
Investment [1]	664,543.01	660,953.67	669,342.88
Profit [1]	49,250.29	58,857.61	103,372.44
Investment return rate [2]	7.41	8.90	15.44
Replacement Enterprise			
Investment [1]	33,670.87	38,103.38	31,342.02
Profit [1]	73,341.35	62,078.89	86,701.13
Investment return rate [2]	117.81	62.92	176.63
System			
Mature Cow [3]	245.65	272.96	223.32
Daily Milk Production[4].	32.38	24.73	40.25
Cow BE volume[5]	28.75	20.60	30.71
Land [6]	15.44	14.42	12.46
Investment [1]	710,939.60	710,939.60	710,939.60
Profit [2]	115,652.47	114,091.02	179,314.66
Investment return rate [2]	16.27	16.05	25.22

(1)US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (cow/liter/day), (6) ha.

Notice that milk price elasticity of investment in the Replacement enterprise is bigger for T2. In addition, T3 elasticity, reported in Table 38, is bigger than for T1, and in T1 the breeds, except CrossHZ are inelastic with respect to the Replacement enterprise investment.

TABLE 38

OPTIMIZED REPRESENTATIVE MODEL BIG FARM
MILK PRICE ELASTICITY OF PRODUCTION FACTOR AND PROFIT

Variables	Brown-Swiss	CrossHZ	Holstein
Mature cows	0.361	0.412	0.346
Land Investment	1.91	1.30	0.343
Profit	-1.75	-1.60	-1.47
Milk enterp. Investment	-0.033	-0.029	-0.011
Rep. Enterp. investment	0.139	0.186	0.125

The final simulation considers milk prices equal to fifteen cents and an increase in the interest rate from six to twelve percent. This simulation is concerned with an increase in the inflation rate reflected by the discount rate. The results are shown in the Table 39, and there is no major change in the investment pattern. The expected effect was the decrease in profit due to an increase in the discount rate. In addition, the elasticity reported in the Table 40 confirms an inelastic Milk enterprise investment and an elastic Replacement investment. T3 is also inelastic with respect to the Replacement enterprise investment, reflecting the change in inflation rate more than a change in the milk price. The same result was obtained for the other farms.

Again, the Milk enterprise investment shows a rigid pattern, with negative elasticity under an increase in the inflation rate. In addition, the system became inelastic including investment in land, which has a negative sign.

Again, the return to scale was tested from T2 to T3 farm level. The three breeds showed return to scale close to 1 with Brown Swiss with 0.95, CrossHZ with 0.94 and Holstein with 0.97.

TABLE 39

OPTIMIZED REPRESENTATIVE MODEL BIG FARM
(Milk price US$0.15 and discount rate 12%)

Variables	Brown-Swiss	CrossHZ	Holstein
Milk Enterprise			
Investment [1]	663,608.19	659,929.45	668,415.91
Profit [1]	47,896.94	57,231.77	101,577.20
Investment return rate [2]	7.22	8.67	15.20
Replacement Enterprise			
Investment [1]	34,750.26	39,277.99	32,357.60
Profit [1]	72,332.69	61,094.38	85,638.26
Investment return rate [2]	108.00	56.00	165.00
System			
Mature Cow [3]	242.86	269.50	221.00
Daily Milk Production[4].	32.38	24.73	40.25
Cow BE volume[5]	28.83	20.68	30.79
Land [6]	15.27	14.23	12.33
Investment [1]	710,939.60	710,939.60	710,939.60
Profit [2]	107,347.84	105,648.32	167,156.61
Investment return rate [2]	15.10	14.86	23.51

(1)US$, (2) %/year, (3) head, (4) liter/cow/day; (5) cow break-even milk production (cow/liter/day), (6) ha.

TABLE 40

OPTIMIZED REPRESENTATIVE MODEL BIG FARM
DISCOUNT RATE ELASTICITY OF PRODUCTION FACTOR AND PROFIT

Variables	Brown-Swiss	CrossHZ	Holstein
Mature cows	-0.011	-0.012	-0.010
Land Investment	-0.046	-0.043	-0.043
Profit	-0.072	-0.074	-0.068
Milk enterprise Investment	-0.002	-0.002	-0.001
Replacement enterprise investment	0.032	0.031	0.032

As affirmed before there are two major inputs to milk production. First is the breed, which is responsible for transforming inputs into milk. The others are the feeds, which are responsible for providing the required nutrients to be transformed into milk and meat. These two important production factors are the kernel of the milk production system and they will be discussed next.

Breed Analysis

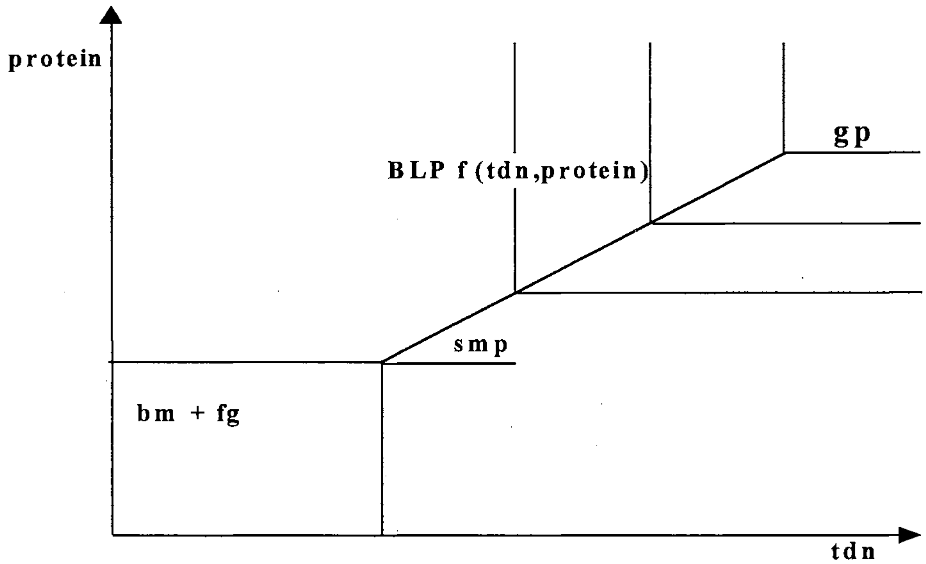
In Brazil, there are six major breeds to produce milk. They are Brown Swiss, Crossbreed Holstein-Zebu (CrossHZ), Gir, Guzerat, Holstein and Jersey. The major characteristics and technical parameters of these breeds can be found in the model appendix.

The cow is the 'machine' transforming inputs (nutrients) into milk. It has three physiological stages – maintenance, fetus growth, and milk production. This work assumes hierarchies among the physiological stages where milk production starts after the other physiological stages have their nutritional requirements completely fulfilled.

As in the NRC tables, the Cornell Net Carbohydrate and Protein System, has a fixed proportion of required nutrients to produce milk. Therefore, there exists a linear milk production function related to a fixed proportion of nutrients. Consequently, after the nutrient requirements for other physiological stages are fulfilled, if there are nutrients available, the milk production follows a linear pattern. The basic idea is shown in Figure 12 considering the two most important nutrients, protein and total digestible nutrient (TDN).

FIGURE 12

BIOLOGICAL LINEAR MILK PRODUCTION ISOQUANTS (BLP)



The square area in Figure 13 represents the amount of protein and tdn required for body maintenance (bm) and fetus growth (fg); consequently, it is not available for milk production. Smp is the slope of the milk production function and is a ratio between protein and tdn. GP is the genetic potential to produce milk, and beyond this line, the cow does not respond to increases in nutrients supplied. These make up a biological linear plateau milk production isoquant (BLP). The area of the schematic representation of the BLP determines the intercept. The BLP parameters depend on the characteristics of the breeds and they are shown in Table 41.

Guzerat has the smaller intercept and Holstein the biggest one. If energy is the costly nutrient, as expected, Jersey cows produce milk most expensively; they produce the highest percentage of fat and the amount of nutrients required to produce milk is positively related to the fat percentage content. Jersey breeds should be important to the markets that pay for fat content.

TABLE 41

PARAMETERS OF THE BIOLOGICAL LINEAR PLATEAU MILK PRODUCTION FUNCTION (BLP)

Variables	Brown-Swiss	Cross HZ	Gir	Guzerat	Holstein	Jersey
Intercept (bm+fg)						
Protein (kg/per day)	0.774	0.537	0.397	0.396	0.754	0.570
TDN (kg/per day)	5.759	4.699	4.496	4.268	5.940	4.355
Milk Production slope						
Protein (kg/per liter)	0.056	0.059	0.061	0.060	0.054	0.059
TDN (kg/per liter)	0.339	0.316	0.338	0.355	0.312	0.367
Intercept/Milk Production (TDN)	16.99	14.87	13.30	12.02	19.03	11.87
Average Production (liters/day)	13.75	10.12	8.52	7.67	19.21	12.19

The tdn in the intercept divided by the tdn in the slope, shows how many liters could be produced with the nutrients expended in the other physiological stages. Only Holstein and Jersey have an ability to use more nutrients to produce more milk than is expended in the other physiological stages.

If the genetic potential to produce milk is low, the breed might make a negative profit because the intercept works as a 'fixed cost' to be paid by the milk produced. Before one liter can be produced, the area (bm+fg) must be satisfied. Higher genetic potential implies a higher probability of achieving a positive profit from the feed consumed.

The implications of this analysis are significant. It implies that, animal with small bodies and consequently a small area (bm+fg) can be more efficient, suggesting the selection of animals with this characteristic. In addition, animals with a steep milk production slope and requiring a small amount of nutrients to produce one liter of milk, are more efficient. This suggests selecting animals with a steeper slope in the milk production curve and/or smaller requirements for milk production.

Feed Analysis

The feed analysis is a relevant part of the milk production system since it is the major input. The basic problem is to find a ration that is as cheap as possible and at the same time fulfills the nutritional requirements of the animals for the three physiological stages. Table 42 shows the cheapest tdn feed supplier and the cheapest protein feed supplier, found in this work.

TABLE 42

CHEAPEST TDN AND PROTEIN SUPPLIERS

Feeds	TDN	Protein
Elephant grass	1	1
Coast-cross	2	3
Brachiaria Brizanta	3	2
Elephant-cutted	4	4
Tanzania Hay	5	5

Elephant grass is the cheapest supplier of energy and protein, and these results agree with the feed selected by the optimization process.

Assume that only tdn and protein change the amount of milk produced. Therefore, all other production factors could be assumed to be constant regarding milk production. Therefore the milk production profit is:

$$\pi_m = Pm * Qm(ytdn, xprot) - Qm * (y * C_{tdn} + x * C_{prot}) - C_{oth} \qquad (1)$$

Where (i) Pm is the milk price. (ii) Qm is the quantity of milk produced; (iii) C_{tdn}

is the cost of tdn to produce one liter of milk, and (iv) C_{prot} is the cost of protein to produce one liter of milk.(v) C_{oth} is the others cost, in this case fixed cost. (vi)Y and (vii) X are the amount of tdn and protein respectively, required to produce one liter of milk.

By the first order condition to maximize profit (FOC) we have:

$$\frac{\partial \pi_m}{\partial Qm} = Pm * (ytdn, xprot) - (y * C_{tdn} + x * C_{prot}) = 0 \qquad (FOC) \tag{2}$$

To produce one liter of milk where ytdn and xprot are the amount of these nutrients required, in each breed to produce one liter of milk, we have:

$$Pm = y * C_{tdn} + x * C_{prot} \tag{3}$$

Equation 3 implies that for maximum profit the milk price should be equal to the cost of producing one liter using 'y' tdn and 'x' protein. Since the total cost of tdn (C_{tdn}) and protein (C_{prot}) are dependent on the amount required in each breed to produce one liter of milk (see Table 41), and also the cost of these nutrients from feeds 'f' we have:

$$Pm \geq \frac{Y_b}{Y_f} * C_{Yf} + \frac{X_b}{X_f} * C_{Xf} \tag{4}$$

Where (i) Y_b is the amount of tdn required for breed 'b' to produce one liter of milk; (ii) Y_f is the amount of tdn supplied by feed 'f'; (iii) C_{Yf} is the cost of tdn from feed 'f'. (iv) X_b is the amount of protein required for breed 'b' to produce one liter of milk. (v) X_f is the amount of protein supplied by 'f'; (vi) C_{Xf} is the cost of protein from feed 'f'.

Equation 4 stated that if the price of milk is greater than or equal to the cost of energy plus the cost of protein, both required per breed 'b' to produce one liter of milk and supplied by feed 'f', then the system breed 'b' associated with feed 'f', has potential to be bio-economically feasible. This equation was expanded to include all six nutrients used in this work. The result of the use of equation 4 considering six nutrients and a milk price equal to US$0.19 is shown in Table 43.

TABLE 43

MARGIN FROM ONE LITER OF MILK PRODUCED

PER BREED 'B' WITH FEED 'F'

Variables	Brown-Swiss	Cross HZ	Gir	Guzerat	Holstein	Jersey
Elephant grass	0.15	0.16	0.16	0.16	0.15	0.16
Coast-cross	0.12	0.12	0.13	0.13	0.11	0.13
Brachiaria Brizanta	0.12	0.13	0.13	0.13	0.12	0.14
Elephant-cutted	0.10	0.11	0.11	0.11	0.09	0.11
Tanzania Hay	0.08	0.09	0.10	0.09	0.07	0.10
Brachiaria Brizanta Hay	-0.01	0.01	0.02	0.02	-0.02	0.03
Sugar Cane	-0.02	0.002	0.009	0.005	-0.03	0.02
Andropogon	-0.21	-0.15	-0.14	-0.15	-0.22	-0.13

Margin is equal to price of milk minus tdn cost plus protein cost, producing one liter of milk with feed 'f' and breed 'b'.

Notice that the feeds chosen in the optimization process are again the most important factors. In addition, some feeds are feasible with some breeds and are not feasible with others reflecting the complexity feed-breed-milk price relation. Other feeds have a negative margin for all breeds. It is important to remember that feeds with a negative margin should not be used as a base feed for the milk production system. However, they can be used as a ration, supplying a specific nutrient, complementing the feed regime. Therefore, Equation 4 is better used to evaluate feasible feeds than for evaluating infeasible feeds.

In addition, the breed requirements and excretion – feed nutrient supply – feed cost impose non-constant marginal costs that require a nonlinear optimization process.

The marginal cost is expected to decrease until the production can be supported using basically the cheapest feed, in this case, elephant grass. After this point, the marginal cost is expected to increase through addition of different, richer and expensive nutrients, growing until the predicted dry matter intake constraint reaches the predicted maximum. More precise marginal costs could be found if palatability constraints for each feed could be provided.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

The major problems in milk production in Brazil are the systematic decreases in profit due to a decrease in the milk price received by farmers and the low productivity of milk production systems. However, while milk producers are facing decreasing profit and are working with low productive system, Brazilian milk production has, nevertheless, been growing quickly. From 1985 to 1998 production grew from 12.57 billions to 21.77 billion liters, corresponding to 73.16% growth. Milk production in Brazil has been growing 39% faster in the last decade than in the decade of the 60s. In addition, from 1993 to 1998 productions per capita increased from 94.8 to 128 liters per capita, corresponding to a 35.02% increase.

This milk production growth is based more on herd size expansion than on productivity gains. Productivity growth explains only 40.61% of the milk production growth from 1990 to 1995, while the herd size expansion explains the remaining 59.39%. However, the productivity of the milk production system is very low compared to international levels. Furthermore, the rate of growth of productivity is small. In brief, the milk production rate grew 3.59% on average per year from 1960 to 1999 with herd expansion explaining the majority of this growth.

While Brazil is a big milk producer, it is still a net dairy importer. Brazil imported more than 18% of butter consumed from 1993 to 1998. Most of Brazil's dairy imports were cheese. The amount of imported cheese during the considered period corresponds to 98.26% of the total produced, implying that half of the Brazilian cheese market has been supplied by imports since the macroeconomic stabilization plan (Real Plan) started. The amount of milk imported corresponded to 10% of the milk produced from 1993 to 1998.

Brazil has more than one million milk farms, 37% of the total farms. The ownership structure is family farming and the milk production is concentrated in farms with 500 hectares or less; 92.83% of the Brazilian milk production comes from these farms. The milk production structure reported in the Brazilian Agricultural Census shows that 65% of the milk production came from cattle-raising farms, and 75% of the milk produced came from specialized herds, where the main purpose of the cow is milk production.

Most studies in Brazil assign the changes ongoing in the Brazilian dairy industry to the forces of market deregulation, the opening of the economy with growing MERCOSUL interactions and the Real Plan. In addition, market imperfections have been suggested as a possible reason for the decreased profit for farmers. On the production side, Alves and Assis (1998), Gomes (1999), and Brandao (1999) indicated high production costs and operational scale as major problems.

Worldwide, several works have studied the impact of a changed market environment, particularly market deregulation. They indicated scale, feed regime, and cow productivity as major variables affecting profit.

These studies simulated different scenarios and analyzed effects of these scenarios on profit, assuming a given resource allocation and technology. However, none of these studies has attempted to simulate free resource allocation and changing technology, simultaneously, in order to predict the future characteristics of the production system under different possible scenarios. Furthermore, the available studies, which represent a specific production system, have difficulty in extrapolating the results to more general cases.

Objectives of the Study

Since farmers are facing a systematic decrease in profits, the objective of this study was to predict the future characteristics of the milk production system under likely future scenarios. In addition, the study evaluated the profitability of current production systems. The study identified specific causes of inefficiency in order to understand the major variables affecting milk production in Brazil.

In addition, to help reach this objective, three hypotheses about increasing profit were stated and evaluated: (i) changing resource allocation can improve profit; (ii) a change in technology can improve profit; (iii) a combination of different resource allocation and a change in technology can improve profit.

Since one characteristic of milk production in Brazil is the diversity of resource allocation and technologies, this study assumes the classification used in Minas Gerais State Diagnostic. It considers small, middle – sized and big farms, which produce 50, greater than 50 and less than 250, and greater than 250 liters per day, respectively. The objectives of this study cover these three farm categories by creating a mathematical model that contains important feature of these farms.

Method and Procedure

To reach the objectives, a mathematical model supported by nonlinear programming theory was specified. The procedure simulated a constrained model, reproducing the resource allocations and technology currently adopted. This constrained model had amounts of land, herd size, breed and cow productivity equal to the farm categories, in this way configuring a representative model. Since the representative models so specified had the same characteristics as the system found in Brazil, their results were expected to be similar to observed outcomes on actual farms. In this way, the analyses of the representative models enabled the evaluation of the economic performance and inefficiencies of the current milk production system, fulfilling the first objective.

The second objective – to evaluate profitability of alternative milk production systems under possible future environments – was achieved by allowing the model to be optimized using different resource allocations and changes in technologies. Breed and cow productivity represent technology, while amount of land, herd size and facilities are variables representing possible resource allocation. This optimization had only investment capacity as a major constraint.

These two blocks of simulations, constrained and free optimization, were conducted under different scenarios. The constrained model considered a scenario with milk price equal to US$0.19 and discount rate equal to 6%. The free optimization considered a milk price equal to US$0.19 and U$ 0.15 and an inflation rate, represented by augmenting discount rate, equal to 6% and 12%.

In order to evaluate the performance of the models, break-even volume, milk prices elasticity and discount rate elasticity of production factor and profit were determined. In addition, marginal values and profit level provided by the optimization process were computed. These results were evaluated in order to understand and assign the future characteristics of the milk production system.

Since breed and feed are the most important production factors and have a complex interdependence, breed and feed analyses were conducted. Breed analyses considered the three cow physiological stages – maintenance, fetus growth and milk production. In addition, a hierarchy among the physiological stages, where milk production comes after requirements for the others are satisfied, was incorporated. Analyses showing the relationship between feed as a fix cost – cost of nutritional requirements for maintenance and fetus grow – and feed as a marginal cost – cost to produce one more liter – were conducted. The feed analysis considered the cost of total digestible nutrients (tdn) and protein supplied in order to evaluate the cheapest sources of these two important nutrients. This analysis used the feed analysis equation.[26]

Results

The constrained model reported positive profit for big farms and negative profit for middle and small farms. Low cow productivity was an evident cause of inefficiency in current milk production practice. The current cow productivity is 4.1, 5.6 and 8.7 liters/cow/day for small, middle – sized and big farms, respectively. However, the required break-evens were 13.86, 13.67 and 14.85 liter per day. The reported marginal values of cow productivity (the additional profit from increasing cow productivity by one

[26] see Feed Analysis in Chapter V for more detail

liter/cow/day) were US$701.51, US$1,737.19, and US$4,394.75 in small, middle and big farms respectively. Considering the available technology, simulation 4 the marginal values of cow productivity is reported in table 44.

TABLE 44

COW PRODUCTIVITY MARGINAL VALUE
(Milk price equal US$0.19 and available technology)

Breeds / farms	T1	T2	T3
Brown-Swiss	1,229.82	3,708.74	10,460.24
CrossHZ	1,397.56	4,214.549	11,886.95
Gir	0.32	0.32	0.32
Guzerat	0.35	0.35	0.35
Holstein	1,150.18	3,468.56	9,782.84
Jersey	1,460.25	4,403.63	12,420.13

Capital and labor elasticity were calculated to be biggest for middle sized farms. Middle – sized farms have a high response to capital allocation and a high response to labor cost. Small farms have negative capital elasticity of profit meaning that if the available capital is increased and allocated in the same proportion as the previous allocation, with the same technology, the small farm will show lower profitability. Labor cost elasticity of profit for big farmers was negative and of high relevance.

There were three major conclusions learned about the current system and its resource allocation and technology. (i) There likely will be a long-run decapitalization for small and middle – sized farms if the current system remains. (ii) There exists a strong economic incentive to migrate to beef production. (iii) There exists a strong economic incentive to adopt a more productive technology, and use different resource allocations for those who want to continue operating milk farms.

The first hypothesis was concerned with resource allocation as a potential instrument to increase profit level. Simulating resource allocation with the same technology tested the first hypothesis. The first hypothesis was not rejected. Therefore, it is concluded that it is economically advisable to improve resource allocation in milk production in Brazil. This simulation showed that: (i) there is too much land allocated to milk production, and (ii) herd sizes are too small. The simulation, which focused on resource allocation, ratified the previous conclusions and emphasized the economic incentive to migrate to beef production.

The results from the resource allocation analyses corresponding to the first hypothesis were as follows: (i) Small farms are better off ceasing production than producing with the current technology. (ii) Middle – sized and big farms have incentive to migrate to beef production and stop milk production. (iii) There exists a strong incentive to reduce the amount of disposable land in the milk system. (iv) There exists an incentive to increase herd size.

The second and third hypotheses considered changes in technology and resource allocation as instruments to improve profits. The simulation used to verify these hypotheses showed that they could not be rejected either.

Change in technology and resource allocation was simulated under different scenarios. First, a simulation considering milk price equal to US$0.19 and a discount rate equal to 6% was conducted for three different farm sizes. When the current average of cow productivity was assumed as upper bound, all breeds, except Guzerat, reported positive profit for system as a whole. However, only Holstein breed reported positive profit to Milk enterprise.

When the cow productivity was increase beyond the current average, the results reported positive profit for all breeds considering the production system as a whole. However, they reported negative Milk enterprise profit for Gir, Guzerat and Jersey breeds and positive Milk enterprise profit for Brown Swiss, CrossHZ, and Holstein breeds.

The breeds with negative profit in the Milk enterprise have smaller milk production than the cow break-even volume required for the investment to be profitable. The breeds with positive profit have a larger milk production than the cow break-even volume than required for the investment to be profitable. Clearly, cow productivity is a 'key' for balanced and profitable milk production system. Comparing the results of the positive breeds with the representative model showed that the major changes in the milk production system resulting from the use of breeds with a positive profit were: (i) a strong reduction in land investment; (ii) an increase in herd size; (iii) and an overall maximization of cow productivity.

In the next step, the three profitable breeds were submitted to scenarios that are more difficult where the milk price decreased to US$0.15 and the inflation rate increased, (adjusting the discount rate to 12%). These simulations indicated that when the inflation rate increased the investment pattern became strongly inelastic for all three farm levels. Simply put, inflation reduces the profit and does not allow any change in the investment pattern in order to reduce its negative effect.

However, under a scenario in which the price is decreased and the economy is stable, the result is quite different allowing different investment patterns. For such a case, the results indicate the following tendencies:(i) an increase in herd size; (ii) an increase in land investment and (iii) an increased investment in a Replacement enterprise to

CrossHZ. The increase in land enterprise indicates that when there is a decrease in price milk production tends to be based on pasture. This result is in agreement with the previous work of Ramsden et al. (1999); Tozer and Huffaker (1999); Berger et al. (1999) and Brockington et al. (1992), among others.

The differences among the small, middle and big farms came only from the amount of profit, as expected with a constant return to scale production function. A constant return to scale, close to one, was reported for all breeds achieving positive profit. Therefore, it was concluded that there is no relationship between capital productivity and size.

Elasticity is very important because it indicates the optimal action under the considered scenario. Because of a genetic potential for high milk production, Holstein and Brown Swiss show a more inelastic investment pattern. CrossHZ, due to its characteristics as a dual – purpose cow and as a cow that requires less feed for maintenance and fetus growth, has a more elastic investment pattern and so permits some flexibility in investment pattern.

The breed analyses showed that: (i) the Guzerat has a smaller feed fixed cost and the Holstein has a bigger feed fixed cost; (ii) the Jersey produces the costliest milk; (iii) the CrossHZ requires less feed for maintenance and fetus growth than the Brown Swiss and the Holstein; (iv) the CrossHZ produces cheaper milk than the Brown Swiss and the Holstein.

The feed analyses showed that: (i) elephant grass is the cheapest supplier of tdn and protein; (ii) coast – cross is the second cheapest supplier of tdn and the third cheapest supplier of protein; (iii) Brachiaria Brizanta is the third cheapest supplier of tdn and the second cheapest supplier of protein.

Conclusions

Several conclusions can be drawn from these results.

1. The analysis of the constrained model, corresponding to milk production in Minas Gerais State and by extension in Brazil, suggests that the current milk production system is unbalanced. The major cause of this inefficiency is cow productivity, because the cow production level is smaller than the break-even volume required for profitable investment in the three farm categories. The results show that there exist relationships between investment and break-even volume. For the CrossHZ – the current technology – the ratio of the investment to the break-even volume per day was found to be US$454.74, US$530.99 and US$494.40 per liter for small, middle and big farms. These ratios show that for a dairy production to be profitable, the total capital investment divided by the amount of milk produced per day must be less than US$530.99, when the milk price equals US$0.19.

2. This study shows that there is too much investment in land. Since land investment increases when the milk price goes down, this study suggests that land productivity must be increased.

3. The representative model has a herd size that is smaller than is required to return a profit on the investment. This conclusion and the previous two suggest that the

current system is unbalanced. Current farms have invested incorrectly with limited capital accessibility.

4. Using the same resource allocation adopted in the representative model, farms with: (i) endowment value around with US$85,000 must produce more than 187 liters/day; (ii) endowment value around US$250,000 must produce more than 476 liters/day; (iii) endowment value around US$710,000 must produce more than 1,437 liters/day. Production smaller than these values is likely to result in a loss for that particular Milk enterprise when the milk prices is equal to US$0.19 or smaller.

5. Small farms adopting the current technology and resource allocation are better off doing nothing rather than engaging in the Milk enterprise. Since Brazil has more than one million small milk producers, this implies a big social and economic change. If only 50% of them adopted the representative model technology, this work implies that around 500,000 small farms in Brazil would have an incentive to change business in the next years. In addition, with 35 cows per farm an average, and considering that small farms have an incentive to move to beef production, this change lets more than 18,040,473 cows to be added to the beef market.

6. Middle – sized farms adopting the current technology and resource allocation are close to the break-even point, but the Milk enterprise is negative while the Replacement enterprise is positive. Therefore, with better resource allocation they will be better off ceasing the production of milk and moving to the beef industry.

However, for those who wish to continue in the milk production business, there exists a strong incentive to adopt more productive milk production technology.

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7. Big farms adopting the current technology and resource allocation are making money, but Milk enterprise profit is negative while Replacement enterprise profit is positive. Therefore, with better resource allocation they will be better off ceasing the production of milk and moving to the beef industry. However, for those who desire to continue in the milk production business, there exists a strong incentive to adopt more productive milk production technology

8. Under the currently average cow productivity found in Brazil, only Holstein breed achieved positive profit and it is economical advisable to farm T1, T2 and T3 investment capacity.

9. Sensitivity analysis did not support the idea that risk from mortality rate in Holstein could be economically significant in farm T1, T2 and T3 investment capacity.

10. There is evidence that Gir, Guzerat and Jersey breed should increase genetic potential to produce milk in order to be competitive in milk production in Brazil. The major problem faced by these breeds is the break-even volume required in each farm level. The genetic potential for milk production for these breeds must be increased by more than 12%, 20%, and 8% for Gir, Guzerat and Jersey, respectively, for them to become competitive.

11. It is concluded that Brown Swiss, CrossHZ and Holstein have genetic potential enough to produce milk competitively in Brazil. They are above the required break-even volume in each farm level.

12. The breed analyses using a linear bio-economic milk production function supports the idea that breeds with small metabolic weight are more efficient for production of milk. Therefore, it is suggested that cows be selected using an index relating milk production to metabolic weight.

13. The breed analyses using a linear bio-economic milk production function also supports the idea that breeds with a steeper linear function should be more efficient in producing milk. Therefore, it may be suggested that cows should be selected using an index relating tdn and protein per liter of milk produced, selecting for animals with smaller tdn and protein excretion. In addition, this analysis reported that the ratio of variable cost to feed cost is equal to 36.67%, 32.71%, 31.94%, 32.00%, 44.11% and 46.27% to Brow Swiss, CrossHZ, Gir, Guzerat, Holstein and Jersey, respectively. It means that from feed cost only that percentage is allocated to produce milk, while the remaining cost is addressed to other physiological stages, assuming here as a fixed cost.

14. When considering feed production and cost, Elephant grass and Coast-Cross are the best grasses for supporting the grazing system in Brazil. They are the cheapest suppliers of tdn and protein.

15. Milk production system has a constant return to scale. The breeds with positive Milk enterprise profit have a reported return to scale close to 1.0.

16. The complexity of the bio-economic production system is strongly related to the amount of capital invested, herd size, cow productivity, and feed regime. The interaction among these factors determines the profit level.

17. Small, middle and big farms should produce milk with Brown Swiss, CrossHZ or Holstein, in supplemented grazing system with elephant and/or Coast-Cross, considering productivity per cow bigger than the break-even volume required for such investment levels.

18. The CrossHz has been a popular cow in milk production in Brazil because it has a comparative advantage, producing the cheapest milk by requiring a smaller amount of tdn and protein than Brown Swiss and Holstein. In addition, it has a less inelastic investment pattern trading off between milk and beef production, giving investment 'flexibility' in situations when inflation and price volatility are expected. This result suggests future research to determine beef price differences among these three breeds as another possible reason to explain the popularity of CrossHZ in Brazil.

19. If a specialized milk production system is expected to be prevalent in milk production in Brazil, then the Holstein is by far the best milk producer, especially in light of the profit maximizer approach.

Limitations of the Study

Like any economic study at the regional or national level, this study suffers from aggregation criticism. In general, economic theory is based on the firm level and extrapolation of the results from this to a national level can lead to distortions.

The model results are sensitive to feed cost and the average production adopted. A change in these parameters can lead to different results with respect to the feed regime suggested. This criticism is valid for all parameters assumed in the model, and is a general limitation of the mathematical programming theory with regard to extrapolation of its results.

Since the models are non-linear and highly sensitive to starting values, theoretically, the results are only locally optimal. This implies that other arrangements in feed-breed-investment could provide theoretically better or equal solutions. However, since the models were tested more than a hundred times and the literature has suggested that GAMS captures the global optimum in 85% of the times it was expected that the presented solutions were, if not unique, at least global.

An important deficit in this study, frequent in modeling, is the absence of management skills influence. Adoption of new technologies probably requires managerial knowledge. This work assumes that farmers are able to manage the technological process they adopt well. This is an item that should be addressed in future studies of this kind.

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APPENDICES

APPENDICES A

SUMMARY OF MODEL VARIABLES AND PARAMETERS

TABLE 45

MODEL VARIABLES AND THEIR DESCRIPTION

Variables	Description	Units
calvesM $_{b,s}$	quantity of calves produced in Milk enterprise (s = 1 female and, s = 2 male)	#animals
calvesR $_{b,s}$	calves produced	# animals
ccostM $_b$	capital cost	dollars
ccostR $_b$	capital cost	dollars
d	discount rate	percentage
fcostM $_b$	feed cost in Milk enterprise	dollars
fcostR $_b$	feed cost	dollars
feedL $_{b,f,l}$	quantity of feed 'f' produced in land type 'l'	Kilos
feedLM $_{b,f}$	quantity of feed 'f' bought from Land enterp.	Kilos
feedLR $_b$	amount of feed 'f' bought from Land enterp.	Kilos
feedM $_{b,f}$	total quantity of feed 'f' bought	Kilos
feedmktM $_{b,f}$	quantity of feed 'f' bought from the market	Kilos
feedmktR $_b$	amount of feed 'f' bought from the market	Kilos
h0Mmkt $_b$	female calves produced and sold to the market	# animals
h0MR $_b$	female calves produced and sold to	# animals
h0Rmkt $_b$	heifers zero-year sold to the market	# animals
h0RR $_b$	remaining heifers zero-year in Replacement	# animals
h1Rmkt $_b$	heifers one-year sold to the market	# animals
h1RR $_b$	remaining heifers one-year in Replacement	# animals
heif1f $_b$	quantity of heifers one-year in the ending of the grow process	# animals
heif2f $_b$	quantity on heifers two-years old in the ending of the grow process	# animals
intakeM $_b$	total cow dry-matter intake	Kilos/day
intakeR $_b$	total cow intake	Kilos/day
invcap $_{T,b}$	farmer level 'T' total investment capacity	dollars
invcowM $_b$	investment in cows	dollars
invcowR $_b$	investment in cows	dollars
invfacM $_b$	investment in facilities	dollars
invfacR $_b$	investment in facilities	dollars
invL $_b$	total investment in Land enterprise	dollars
invlandM $_b$	investment in land	dollars
invlandR $_b$	investment in land	dollars
invM $_b$	total investment in Milk enterprise	dollars
invR $_{,b}$	total investment in Replacement enterprise	dollars
int	interested rate	percentage
$L\pi_b$	Land enterprise profit	dollars
labcostM $_b$	labor cost	dollars
labcostR $_b$	labor cost	dollars
$M\pi_b$	Milk enterprise profit	dollars
mbreed $_b$	desired milk production per head	liters/day
mcost $_b$	total cost in Milk enterprise	dollars
nmilk $_{b,N}$	total required nutrient 'N' to produce milk	Kilos & Mcal
nother $_{b,N,St}$	Nutrient 'N' to physiological stages (st) others than to milk production	Kilos & Mcal
NPV $_b$	net present value of the one-year milk production system profit	dollars
nsupM $_{b,N}$	quantity of nutrient 'N' supplied	Kilos & Mcal
nsupR $_{b,N}$	total nutrient 'N' supplied	Kilos and Mcal
nutdemM $_{b,N}$	total nutrient 'N' demanded	Kilos & Mcal
nutdemR $_{b,N}$	total nutrient 'N' demanded	Kilos and Mcal
ocostM $_b$	other cost (transport, energy, services and taxes)	dollars
Variables	Description	Units
ocostR $_b$	other cost (transport, energy, services, and taxes)	dollars

Variables	Description	Units
$pcalves_b$	price of calves	dollars
$pcow_b$	price of cows	dollars
$pheif_b$	price of heifers	dollars
$qbeefM_b$	quantity of beef produced	Kilos/year
$qbeefR_b$	quantity of beef produced	Kilos
qcl_b	quantity of lactating cows	# cows
qcm_b	herd size	# cows
qcp_b	quantity of pregnant cows	# cows
qcR_b	herd size	# animals
$qheifmktM_b$	quantity of heifers bought from the market	# animals
$qheifRM_b$	quantity of heifers sold to Milk enterprise	# animals
$qheifRmkt_b$	quantity of heifers sold to the market	# animals
qm_b	quantity of milk produced	liters/year
$R\pi_b$	Replacement enterprise profit	dollars
$rcost_b$	total cost	dollars
$repcostM_b$	replacement cost	dollars
$s0Mmkt_b$	male calves produced and sold to the market	# animals
$s0MR_b$	male calves produced and sold to Replacement enterprise	# animals
$s0Rmkt_b$	steer zero-year sold to the market	# animals
$s0RR_b$	remaining steer zero-year in Replacement	# animals
$s1Rmkt_b$	quantity of steers one-year sold to the market	# animals
$s1RR_b$	remaining steers one-year in Replacement	# animals
$steer1f_b$	quantity of steer one-year in the ending of the grow process	# animals
$steer2f_b$	steer two-years in the ending of the grow process	# animals
$steerRmkt_b$	quantity of steers two-year sold to the market	# animals
$vetcostM_b$	veterinary care cost	dollars
$vetcostR_b$	veterinary care cost	dollars

(i)'b' – breeds; (ii) M – Milk enterprise; (iii) R – Replacement enterprise; (iv) L – Land enterprise; (v) T – farm size.

TABLE 44

MODEL PARAMETERS AND THEIR DESCRIPTION

Parameters	Description	Units
abt	Abortion rate	Percentage
cornratio	Milk – corn price ratio	dollars
$cphs_{st}$	cow physiological stages (st = maintenance and pregnancy)	-
$culling_b$	culling rate	percentage
cw_b	average cow weight	Kilos
$death_b$	death rate	percentage
$dgainh_b$	adopted daily gain for heifers	Kilo/day
$dgains_b$	adopted daily gain for steers	Kilo/day
$endow_T$	Endowment value	Dollars
env	environment Conditions (temp., humidity etc)	-
$fertil_b$	fertility rate	percentage
int	Interest rate	percentage
gp_b	genetic potential for milk production	liters/day
pbeef	beef price	dollars
$pcost_f$	feed 'f' production cost	dollar/Kg-DM
$Pcost_f$	production cost of feed 'f'	dollars
plab	price of labor	dollar/cow
pmilk	milk price	dollars
$predintM_b$	dry-matter intake predicted in Milk enterp	Kilo/day
$predintR_b$	predicted dry-matter intake in Replacement	Kilo/day

APPENDICES B

FARM CATEGORIES AND INVENTORY CALCULATIONS

Small Farmers' Inventory Producing Less than 50 liters per day

Variable	Quant.	Price (US$)	Total (US$)		
Land (HA)	40.74	$824.18	**$33,577.09**		
Animals					
Bull	0.88	$605.60	$532.93		
Lactating cows	8.27	$1,239.05	$10,246.92		
Dried cows	6.86	$1,239.05	$8,499.86		
Total mature cows	16.01		$19,279.71		
Heifers 2 year	3.69	$1,189.62	$4,389.71		
Steer 2 year	0.9	$605.60	$545.04		
Heifers 1 year	4.47	$396.54	$1,772.54		
Steer 1 year	6.74	$302.80	$2,040.87		
Steer 0 year	3.86	$100.93	$389.60		
Total growing animals	19.66		$9,137.77		
Total animals (herd size)	35.67		**$28,417.48**		
Facilities					
27.10% of the total capital	0.271		**$23,046.00**		
Facilities/cow			$646.09		
Total Inventory			**$85,040.57**		
Labor productivity					
liters/day/person	29				
Total production	33.91				
Total required labor	1.17				
cow/worker	30.51				
Daily Labor cost	$7.46				
Total daily labor cost/cow	$0.24				
Bull Price (aver. weight*Pbeef)		**$605.60**			
Lactating cow price		**$1,239.05**			
Intercept cow price	-2485				
param. genetic potential (mbreed)	37.0567				
param. Corn/milk price ratio	633.6802			**Heifers price**	**$1,189.62**
param. Beef price	2478			Intercept heifer price	-4433
param. Interest rate	-742.07			param. genetic potential	52.1331
average mbreed	4.1			param. milk price	30251
milk price/corn ration	1.486233			milk price	0.1788
Beef price	1.21120				
1/Interst rate	0.5				

Middle Farmers' Inventory (greater than 50 and less than 250 liters per day)

Variable	Quant.	Price (US$)	Total (US$)
Land (HA)	134.64	$824.18	**$110,967.60**
Animals			
Bull	1.6	$605.60	$968.96
Lactating cows	25.39	$1,237.26	$31,414.11
Dried cows	15.82	$1,237.26	$19,573.50
Total mature cows	42.81		$51,956.57
Heifers 2 year	9.99	$1,265.22	$12,639.52
Steer 2 year	4.2	$605.60	$2,543.52
Heifers 1 year	12.4	$421.74	$5,229.57
Steer 1 year	20.9	$302.80	$6,328.52
Steer 0 year	12.1	$100.93	$1,221.29
Total growing animals	59.59		$27,962.42
Total animals (herd size)	102.4		**$79,919.00**
Facilities			
24.59% of the total capital	0.2459		**$62,245.08**
Facilities/cow			$607.86
Total Inventory			**$253,131.67**
Labor productivity			
liters/day/person	61.04		
Total production	140.91		
Total required labor	2.31		
cow/worker	44.36		
Daily Labor cost	$7.46		
Total daily labor cost/cow	$0.17		

Bull Price (aver. weight*Pbeef)		**$605.60**
Lactating cow price		**$1,237.26**
Intercept cow price	-2485	
param. genetic potential (mbreed)	37.0567	
param. Corn/milk price ratio	633.6802	
param. Beef price	2478	
param. Interest rate	-742.07	
average mbreed	5.55	
milk price/corn ration	1.398623	
Beef price	1.21120	
1/Interst rate	0.5	

Heifers price	**$1,265.22**
Intercept heifer price	-4433
param. genetic potential	52.1331
param. milk price	30251
milk price	0.1788

Big Farmers' Inventory (greater than 250 liters per day)

Variable	Quant.	Price (US$)	Total (US$)	
Land (HA)	343.23	$824.18	**$282,883.30**	
Animals				
Bull	2.84	$605.60	$1,719.90	
Lactating cows	69.98	$1,408.40	$98,559.59	
Dried cows	40.39	$1,408.40	$56,885.13	
Total mature cows	113.21		$157,164.62	
Heifers 2 year	29.11	$1,427.87	$41,565.38	
Steer 2 year	22.14	$605.60	$13,407.98	
Heifers 1 year	33.11	$475.96	$15,758.96	
Steer 1 year	57.74	$302.80	$17,483.67	
Steer 0 year	27.82	$100.93	$2,807.97	
Total growing animals	169.92		$91,023.95	
Total animals (herd size)	283.13		**$248,188.58**	
Facilities				
25.30% of the total capital	0.253		**$179,867.72**	
Facilities/cow			$635.28	
Total Inventory			**$710,939.60**	
Labor productivity				
liters/day/person	94.71			
Total production	606.73			
Total required labor	6.41			
cow/worker	44.20			
Daily Labor cost	$7.46			
Total daily labor cost/cow	$0.17			
Bull Price (average weight*Pbeef)		**$605.60**		
Lactating cow price		**$1,408.40**		
Intercept cow price	-2485			
param. genetic potential (mbreed)	37.0567			
param. Corn/milk price ratio	633.6802			
param. Beef price	2478		**Heifers price**	**$1,427.87**
param. Interest rate	-742.07		cept heifer price	-4433
average mbreed	8.67		param. genetic potential	52.1331
milk price/corn ration	1.486233		param. milk price	30251
Beef price	1.21120		milk price	0.1788
1/Interst rate	0.5			

APPENDICES C

GAMS / MINOS CODE FOR THE MODEL

GAMS / MINOS CODE FOR THE MODEL

```
$ Title BRAZILIAN MILK PRODUCTION SYSTEM
option limrow=0, limcol=0;
option decimals=2;
option iterlim=200000;
option reslim=30000;

********************************************************************************
* Model SETS
********************************************************************************
SETS
b     Breeds
/Brown-Swiss, CrossHZ, Gir, Guzerat, Holstein, Jersey/

bop(b) Breeds to be optimized
/CrossHZ/

L     Land characteristics
/mont, hill, Pldried, Plhum/

n     Nutrients
/Dry-matter,Protein, Energy, TDN, Ca, P,NDF,K /

f     Milk Production Feeds
/ oathay,ele_graz,ele_sil, ele_cut,ele_hay,ccros_gras,ccros_hay,Brizangras,
brizanhay,BrachGras, Brachhay,setarhay,setargras,Jargras,Jarahay,TanzHay,alfahay,
alfasil,leuchay,cornsil,corngrain,sorgrain,scane,soy_grain,soy_meal,cotton-seed,
cotton_meal,wheat_meal,ureia,molasses,citrus-pel,citrus_pup,corn_rolao,blood_meal,
brewers_hum,meatbl_meal,meat_meal,poult_bed,corn_broken,Guinehay,lime,Fbicalc,
bicarb,milkfresh,alfagras,yeast,scanehid,Andropogon/

p(f) Milk Production Feeds produced in Farmland
/oathay,ele_graz,ele_sil,ele_cut,ele_hay,brizangras,brizanhay,Tanzhay,ccros_gras,
ccros_hay,alfahay,alfasil,alfagras,leuchay,cornsil,corngrain,corn_rolao,sorgrain,
scane,soy_grain,BrachGras,Brachhay,setarhay,Jarahay,Guinehay,Andropogon/

m(f) Available Feeds in the market
/alfahay,soy_grain,soy_meal,cotton-seed,cotton_meal,wheat_meal,ureia,
 molasses,corn_rolao,blood_meal,brewers_hum,meatbl_meal,meat_meal,
 citrus_pup,poult_bed,corn_broken,corngrain,sorgrain,lime,Fbicalc,bicarb,
milkfresh,yeast,scanehid/

var variable used to construct table results
/ Endow,qcm,qcl,mbreed,PcowM,qtm,heif1i,heif2i,Pheif,steer1i,steer2i,Psteer,
qtR,buyland,Qprod2L,mp,revMM,revbM,fcostM,CcostM,LcostM,repcostM,MccostM,OcostM,
VrcostM,FxcM,TcostM,MargcostM,InvM,profM,DiscrateM,Bevol,revR,FcostR,CcostR,LcostR,
MccostR,RepcostR,OcostR,VrcostR,FxcostR,TcostR,MargcostR,InvR,ProfR,DiscrateR,Netz,
Discrate/
;

********************************************************************************
* Model Paramenters
********************************************************************************

PARAMETERS
Endow(b) The current value of the Milk Farmer Inventory (US$)
/Brown-Swiss      85040.57
```

CrossHZ 85040.57
Gir 85040.57
Guzerat 85040.57
Holstein 85040.57
Jersey 85040.57/

gp(b) Current milk production (kg per day in 305 days - Martinez 2000)
/Brown-Swiss 13.75
CrossHZ 10.12
Gir 8.52
Guzerat 7.67
Holstein 19.21
Jersey 12.19/

****
* Genetic Potential to milk production in Breed 'b'
****
*gp(b) Current genetic portential for milk production (kg per day in 305 days)
*/Brown-Swiss 51.14
*CrossHZ 39.34
*Gir 32.79
*Guzerat 24.59
*Holstein 61.29
*Jersey 19.67/

IntM(b) Intercept of the cow price function
/Brown-Swiss -2485
CrossHZ -2485
Gir -2485
Guzerat -2485
Holstein -2485
Jersey -2485/

pgp(b) Parmater of the milk production in the cow price function
/Brown-Swiss 37.0567
CrossHZ 37.0567
Gir 37.0567
Guzerat 37.0567
Holstein 37.0567
Jersey 37.0567/

pmp(b) Parmater of the milk-corn price ratio in the cow price function
/Brown-Swiss 633.6802
CrossHZ 633.6802
Gir 633.6802
Guzerat 633.6802
Holstein 633.6802
Jersey 633.6802/

Ppbeef(b) Paramenter of beef price in cow price function
/Brown-Swiss 2478
CrossHZ 2478
Gir 2478
Guzerat 2478
Holstein 2478
Jersey 2478/

Pint(b) Parameter of interest rate in cow price function
/Brown-Swiss -742.07
CrossHZ -742.07
Gir -742.07
Guzerat -742.07

Holstein -742.07
Jersey -742.07/

IntR(b) Intercept of the heifer price function
/Brown-Swiss -4433
CrossHZ -4433
Gir -4433
Guzerat -4433
Holstein -4433
Jersey -4433/

pemp(b) Parmater of the expected milk production in the heifer price function
/Brown-Swiss 52.133
CrossHZ 52.133
Gir 52.133
Guzerat 52.133
Holstein 52.133
Jersey 52.133/

pmph(b) Parmater of the Milk price in the heifer price function
/Brown-Swiss 30251
CrossHZ 30251
Gir 30251
Guzerat 30251
Holstein 30251
Jersey 30251/

W(b) Mature Cow weight (kg)
/Brown-Swiss 600
CrossHZ 500
Gir 450
Guzerat 460
Holstein 620
Jersey 450/

bweig(b) Weight at the first breeding (kg)
/Brown-Swiss 380
CrossHZ 300
Gir 300
Guzerat 320
Holstein 350
Jersey 230/

culling(b) Culling-rate in percentage
/Brown-Swiss 0.20
CrossHZ 0.20
Gir 0.20
Guzerat 0.20
Holstein 0.20
Jersey 0.20 /

death(b) Cow death rate in percentage
/Brown-Swiss 0.01
CrossHZ 0.01
Gir 0.01
Guzerat 0.01
Holstein 0.01
Jersey 0.01 /

```
*******************************************************************************
* Percentage of cows in the lactating period calculated as a proportion of ideal
* calving interval (365 days) and the calving interval of the breed 'b'
*******************************************************************************
Cint(b) Proportion of mature cows in the lactating period
/Brown-Swiss    0.785
CrossHZ         0.871
Gir             0.742
Guzerat         0.800
Holstein        0.913
Jersey          1 /

abt(b) Abortion rate
/Brown-Swiss    0.015
CrossHZ         0.015
Gir             0.015
Guzerat         0.015
Holstein        0.015
Jersey          0.015 /

fertil(b) Fertility rate
/Brown-Swiss    0.91
CrossHZ         0.75
Gir             0.75
Guzerat         0.75
Holstein        0.75
Jersey          0.80 /

Calv(b) Calving Interval in months
/Brown-Swiss    15.30
CrossHZ         13.97
Gir             16.4
Guzerat         15.2
Holstein        13.33
Jersey          12.17/

fat(b)  Fat in milk produced
/Brown-Swiss    0.045
CrossHZ         0.040
Gir             0.046
Guzerat         0.049
Holstein        0.039
Jersey          0.052 /

Prot(b)  Protein in milk produced
/Brown-Swiss    3.6
CrossHZ         3.9
Gir             4.0
Guzerat         3.9
Holstein        3.5
Jersey          3.8 /

PredintM(b) Predicted Dry Matter intake for mature cows
/Brown-Swiss    16.02
CrossHZ         12.66
Gir             9.15
Guzerat         9.21
Holstein        17.64
Jersey          13.01 /
```

Preheif0(b) Predicted Dry-Matter intake for growing heifers (0 to 1 year)
/Brown-Swiss 4.35
CrossHZ 3.70
Gir 3.51
Guzerat 3.62
Holstein 4.65
Jersey 3.62 /

Preheif1(b) Predicted Dry-Matter intake for growing heifers (1 to 2 year)
/Brown-Swiss 10.30
CrossHZ 6.04
Gir 6.96
Guzerat 6.31
Holstein 10.25
Jersey 8.30 /

PreSteer0(b) Predicted Dry-Matter intake for growing steers (0 to 1 year)
/Brown-Swiss 4.26
CrossHZ 3.50
Gir 3.14
Guzerat 3.27
Holstein 4.37
Jersey 3.43 /

Presteer1(b) Predicted Dry-Matter intake for growing steers (1 to 2 year)
/Brown-Swiss 8.45
CrossHZ 6.96
Gir 6.27
Guzerat 6.57
Holstein 8.42
Jersey 5.76 /

Vetcare(b) Veterinary care cost and insemination cost per head
/Brown-Swiss 47.34
CrossHZ 22.17
Gir 22.17
Guzerat 22.17
Holstein 47.34
Jersey 47.34 /

Ocost(b) Other cost per head (materials energy fuel tax maintenace)
/Brown-Swiss 96.70
CrossHZ 30.87
Gir 30.87
Guzerat 30.87
Holstein 96.70
Jersey 96.70 /

binwh(b) Heifer birth weight (kg)
/Brown-Swiss 39
CrossHZ 32
Gir 29
Guzerat 28
Holstein 37
Jersey 22 /

binws(b) Steer birth weight (kg)
/Brown-Swiss 42
CrossHZ 38
Gir 35
Guzerat 29
Holstein 42.5

```
Jersey          25 /

Ageb(b) Define the age at the first calving (days)
/Brown-Swiss    780
CrossHZ         960
Gir             1350
Guzerat         1326
Holstein        780
Jersey          690/

Tdayemp(b) Total days emputy of mature milking cows
/Brown-Swiss    85
CrossHZ         85
Gir             85
Guzerat         85
Holstein        85
Jersey          85/

**********************************************************************************
* Tadjheif is Calculated as a ratio between 24 months as ideal age to calving
* and the age at the first calving in each breed (months)
**********************************************************************************
Tadjheif(b) Percentage of heifers 1 year that will be pregnant (year 2)
/Brown-Swiss    0.900
CrossHZ         0.750
Gir             0.533
Guzerat         0.543
Holstein        0.9231
Jersey          1 /

DeathH(b) Mortality rate for heifers
/Brown-Swiss    0.03
CrossHZ         0.05
Gir             0.05
Guzerat         0.02
Holstein        0.05
Jersey          0.05 /

deathS(b) Mortality rate for steers
/Brown-Swiss    0.03
CrossHZ         0.05
Gir             0.05
Guzerat         0.05
Holstein        0.05
Jersey          0.05 /

Pcost(f) Define the production cost ("dollar per kg" of DM)
/oathay          1.29423
 ele_graz        0.01236
 ele_sil         0.04057
 ele_cut         0.03025
 ele_hay         0.05574
 brizangras      0.02042
 brizanhay       0.06298
 Tanzhay         0.03527
 ccros_gras      0.02313
 ccros_hay       0.04664
 alfahay         0.13483
 alfasil         0.19000
 alfagras        0.25200
 leuchay         0.06904
 cornsil         0.12806
```

corngrain	0.12679
sorgrain	0.07186
corn_rolao	0.07137
scane	0.06660
soy_grain	0.17888
BrachGras	0.04607
Brachhay	0.07558
setarhay	0.09577
Jarahay	0.09293
Guinehay	0.04956
Andropogon	0.15032 /

Mprice(f) Define the market price dollar per kg of feed (f)

/alfahay	0.2331
soy_grain	0.1859
soy_meal	0.2503
cotton-seed	0.0974
cotton_meal	0.1025
wheat_meal	0.0739
ureia	0.2308
molasses	0.0958
corn_rolao	0.0726
blood_meal	0.2996
brewers_hum	0.0508
meatbl_meal	0.2308
meat_meal	0.2365
citrus_pup	0.1118
poult_bed	0.0454
corn_broken	0.1354
corngrain	0.12784
sorgrain	0.07186
lime	0.03296
Fbicalc	0.26923
bicarb	0.54951
milkfresh	0.17000
yeast	0.10423
scanehid	0.49554 /

Avp(f) Average production of feed (f) in kg Of MS per hectare per day

/oathay	5.90684
ele_graz	98.63
ele_sil	98.63
ele_cut	98.63
ele_hay	98.63
brizangras	32.880
brizanhay	32.880
Tanzhay	51.7260
ccros_gras	61.6438
ccros_hay	61.6438
alfahay	58.5206
alfasil	58.5206
leuchay	41.0959
cornsil	27.9452
corngrain	14.4660
corn_rolao	18.6300
scane	88.5616
soy_grain	7.56200
sorgrain	4.52631
BrachGras	27.3973
Brachhay	27.3973
setarhay	32.8767
Jarahay	21.9178

```
 Guinehay       41.0959
 alfagras       16.4383
 Andropogon     16.4383  /

Landprop(l) Proportion of the land available quantity (ha)
/mont           0.1229
hill            0.3834
Pldried         0.3755
Plhum           0.1191 /


DiscrateM(b)      Investment return rate in Milk enterprise
DiscrateR(b)      Investment return rate in Replacement enterprise
Discrate(b)       Investment return rate in Whole System
margcostM(b)      Marginal Cost in Milk enterprise
margcostR(b)      Marginal Cost in Replacement enterprise
nutcostL(f,n)     Cost of nutrient 'n' in feed 'f' from farmland production
nutcostmkt(f,n)   Cost of nutrient 'n' in feed 'f' from market
Bevol(b)          Break-even  volume fro System as a whole
cowdebt(b)        Cow debt
feedrel(b)        Nutrient x Protein to maintenance and fetus grow
Prodweig(b)       Milk production lived Weight ration
prodslop(b)       Milk production linear function slope
cowprof(b)        Profit per lactating cow
cowdisc(b)        Investment return rate in Milk enterprise
cowBEvol(b)       Cow break-even volume
cowfeedL(b,p)     Margin of farmland feed 'f' considering breed 'b'requirements
cowfeedmkt(b,m)  Margin of market feed 'f' considering breed 'b'requirements

*******************************************************************************
*  Auxiliar parameter in loop to find start values
*******************************************************************************
heif3(b)          Auxiliar parameter into loop to find start values for heif
steer3(b)         Auxiliar parameter into loop to find start values for steer
MBREED2(B)        Auxiliar parameter into loop to find start values for
QCM2(B)           Auxiliar parameter into loop to find start values for
*******************************************************************************
;

*******************************************************************************
* Relationship between feed and land characteristics. Where 1 represent the
* possibility of feed 'p' grows in land type 'l'
*******************************************************************************
Table tLand(p,l) Type of Land required by feed
                 mont      hill       Pldried    Plhum
 oathay                               1          1
 ele_graz                  1          1
 ele_sil                   1          1
 ele_cut                   1          1
 ele_hay                   1          1
 brizangras      1         1          1
 brizanhay                 1          1
 Tanzhay                   1          1
 ccros_gras                           1
 ccros_hay                            1
 alfahay                              1
 alfasil                              1
 alfagras                             1
 leuchay                   1          1
 cornsil                   1          1
 corngrain                 1          1
 corn_rolao                1          1
```

```
sorgrain                1       1
scane                   1       1
soy_grain               1       1
BrachGras       1       1       1
Brachhay                1       1
setarhay                1       1       1
Jarahay                 1       1
Guinehay                1       1
Andropogon      1       1       1       1
;********************************************************************************
* Daily requirements considering the physiological stages and calculated using
* Cornell Net Carbohydrate and Protein System
*********************************************************************************
TABLE Milk1(b,n) Daily Required Nutrients (maintenance lactating cows - kg)
              Dry-matter Protein  Energy  TDN     Ca     P      NDF   K
Brown-Swiss   6.62       0.593    17.07   4.7291  0.014  0.016  4.50  0.042
CrossHZ       5.51       0.473    14.93   4.1362  0.010  0.013  3.50  0.035
Gir           4.57       0.339    14.39   3.9866  0.008  0.012  2.80  0.032
Guzerat       4.68       0.34     14.71   4.0753  0.008  0.012  2.80  0.032
Holstein      6.09       0.583    17.91   4.9618  0.015  0.017  4.90  0.043
Jersey        4.83       0.468    13.62   3.7733  0.009  0.012  3.60  0.032
;

TABLE Milk2(b,n) Daily Required Nutrients (pregnancy of lactating cows - kg)
              Dry-matter  Protein  Energy  TDN     Ca     P      NDF      K
Brown-Swiss   0.000001    0.181    3.72    1.0306  0.006  0.004  0.00001  0.001
CrossHZ       0.000001    0.064    2.03    0.5624  0.006  0.004  0.00001  0.001
Gir           0.000001    0.058    1.84    0.5098  0.006  0.004  0.00001  0.001
Guzerat       0.000001    0.056    1.78    0.1931  0.006  0.004  0.00001  0.001
Holstein      0.000001    0.171    3.53    0.9780  0.006  0.004  0.00001  0.001
Jersey        0.000001    0.102    2.10    0.5818  0.006  0.004  0.00001  0.001
;

TABLE Milk3(b,n) Daily Required Nutrients per kg of milk produced
              Dry-matter  Protein  Energy   TDN     Ca      P       NDF      K
Brown-Swiss   0.000001    0.05556  1.22182  0.3389  0.0014  0.0009  0.00001  0.0016
CrossHZ       0.000001    0.05988  1.14032  0.3159  0.0015  0.0009  0.00001  0.0016
Gir           0.000001    0.06096  1.22145  0.3384  0.0015  0.0009  0.00001  0.0016
Guzerat       0.000001    0.06023  1.28292  0.3554  0.0016  0.0009  0.00001  0.0016
Holstein      0.000001    0.05383  1.12754  0.3124  0.0014  0.0009  0.00001  0.0016
Jersey        0.000001    0.05849  1.32232  0.3666  0.0015  0.0009  0.00001  0.0016
;

TABLE DP(b,n) Daily Required Nutrients for Dry & Pregnat mature cows
              Dry-matter  Protein  Energy  TDN     Ca     P      NDF  K
Brown-Swiss   6.34        0.728    25.30   7.0091  0.050  0.032  4.2  0.034
CrossHZ       7.15        0.703    19.70   5.4577  0.045  0.028  3.5  0.045
Gir           6.43        0.612    17.67   4.8953  0.042  0.026  3.1  0.041
Guzerat       6.02        0.581    17.58   4.8704  0.043  0.026  3.2  0.042
Holstein      9.55        0.876    23.73   6.5742  0.051  0.036  4.3  .056
Jersey        5.47        0.501    17.16   5.0311  0.042  0.026  2.8  0.041
;

TABLE Theif0(b,n) Daily Required Nutrients for growing heifers (0 to 1 year)
              Dry-matter  Protein  Energy  TDN     Ca     P      NDF  K
Brown-Swiss   1.91        0.493    13.54   3.7511  0.026  0.016  1.2  0.017
CrossHZ       1.56        0.405    11.05   3.0613  0.020  0.012  1.1  0.014
Gir           1.49        0.388    9.42    2.6097  0.017  0.011  2.4  0.012
Guzerat       1.64        0.329    9.25    2.5626  0.016  0.010  2.3  0.013
Holstein      3.04        0.396    10.41   2.8839  0.014  0.010  1.9  0.016
Jersey        1.50        0.387    10.27   2.8452  0.018  0.010  1.5  0.012
;
```

TABLE Theifl(b,n) Daily Required Nutrients for growing heifers (1 to 2 year)

	Dry-matter	Protein	Energy	TDN	Ca	P	NDF	K
Brown-Swiss	4.49	0.945	28.27	7.8320	0.065	0.042	2.6	0.040
CrossHZ	2.53	0.684	20.63	5.7154	0.052	0.025	1.7	0.024
Gir	3.35	0.706	19.20	5.3192	0.044	0.023	1.8	0.025
Guzerat	2.32	0.713	21.75	6..0257	0.056	0.028	1.7	0.026
Holstein	5.25	0.913	25.40	7.0369	0.056	0.038	2.6	0.038
Jersey	4.17	0.739	21.84	6.0506	0.023	0.018	2.1	0.024

;

TABLE TSteer0(b,n) Daily Required Nutrients for growing steers (0 to 1 year)

	Dry-matter	Protein	Energy	TDN	Ca	P	NDF	K
Brown-Swiss	1.96	0.370	10.80	2.9921	0.017	0.011	1.4	0.015
CrossHZ	1.58	0.386	10.01	2.7732	0.018	0.011	1.2	0.013
Gir	1.15	0.382	9.93	2.7510	0.019	0.011	1.4	0.012
Guzerat	1.21	0.294	9.57	2.6513	0.018	0.011	1.3	0.012
Holstein	1.92	0.414	10.75	2.9782	0.017	0.012	2.0	0.015
Jersey	1.63	0.346	8.94	2.4768	0.015	0.009	1.3	0.011

;

TABLE Tsteer1(b,n) Daily Required Nutrients for growing steers (1 to 2 year)

	Dry-matter	Protein	Energy	TDN	Ca	P	NDF	K
Brown-Swiss	4.85	0.717	19.63	5.4383	0.039	0.023	1.1	0.028
CrossHZ	3.51	0.643	18.00	4.9868	0.037	0.022	1.3	0.024
Gir	2.46	0.631	17.84	4.9424	0.040	0.020	0.7	0.022
Guzerat	2.99	0.626	16.66	4.6155	0.035	0.018	1.3	0.022
Holstein	4.13	0.776	22.37	6.1974	0.049	0.028	1.0	0.030
Jersey	3.00	0.623	17.35	4.8067	0.037	0.019	0.7	0.022

;

****
* Table with feed nutrient content using Cornell Net Carbohydrate System
* tropical feed Library
****

TABLE fednut(f,n) Composition of feeds commonly used in dairy (kg & mcal per kg)

	Dry-matter	Protein	Energy	TDN	Ca	P	NDF	k
alfahay	1	0.050	1.63	0.470	0.016	0.003	0.669	0.021
alfasil	1	0.074	2.16	0.590	0.019	0.003	0.435	0.023
alfagras	1	0.224	2.13	0.580	0.004	0.001	0.460	0.048
Andropogon	1	0.221	1.95	0.54	0.001	0	0.700	0.003
brizangras	1	0.066	2.01	0.550	0	0	0.764	0
brizanhay	1	0.067	2.18	0.590	0	0	0.752	0
blood_meal	1	0.329	0	0	0.004	0.003	0	0.001
brachGras	1	0.065	2.01	0.550	0	0	0.758	0
brachhay	1	0.055	1.86	0.520	0	0	0.842	0
brewers_hum	1	0.188	3.45	0.870	0.003	0.006	0.580	0.001
ccros_gras	1	0.051	1.96	0.540	0.005	0.003	0.798	0
ccros_hay	1	0.080	2.13	0.580	0.004	0.002	0.755	0.016
corngrain	1	0.076	3.63	0.920	0.001	0.003	0.134	0.004
cornsil	1	0.077	2.60	0.690	0.003	0.003	0.532	0.011
corn_broken	1	0.077	3.56	0.900	0	0.004	0.011	0.004
corn_rolao	1	0.118	3.21	0.820	0.001	0.003	0.214	0.005
cotton-seed	1	0.110	3.52	0.890	0.002	0.004	0.441	0.005
cotton_meal	1	0.101	2.40	0.640	0.001	0.011	0.469	0.001
citrus_pup	1	0.057	3.06	0.790	0.022	0.001	0.182	0.007
ele_graz	1	0.059	1.95	0.540	0.005	0.003	0.740	0.013
ele_sil	1	0.059	1.81	0.510	0	0	0.784	0
ele_cut	1	0.059	1.95	0.540	0.005	0.003	0.740	0.013
ele_hay	1	0.067	2.18	0.590	0	0	0.658	0
Jarahay	1	0.085	2.22	0.600	0	0	0.728	0
Leuchay	1	0.081	1.74	0.490	0.023	0.002	0.643	0
meatbl_meal	1	0.092	0	0	0	0	0	0

```
meat_meal      1          0.120   0      0.722   0       0       0       0
molasses       1          0.236   2.76   0.720   0.001   0.001   0       0.032
poult_bed      1          0.061   2.09   0.570   0.036   0.021   0.391   0.018
scane          1          0.056   2.39   0.640   0.004   0.002   0.571   0.011
setarhay       1          0.101   2.55   0.670   0       0       0.669   0
sorgrain       1          0.075   3.70   0.930   0.001   0.003   0.112   0.005
soy_grain      1          0.130   4.96   1.220   0.003   0.007   0.191   0.009
soy_meal       1          0.088   3.37   0.860   0.003   0.007   .141    0.022
wheat_meal     1          0.074   2.85   0.740   0       0       0.430   0
ureia          1          1.000   0      0       0       0       0       0
Tanzhay        1          0.077   2.21   0.600   0       0       0.677   0
lime           1          0       0      0       0.370   0       0       0
Fbicalc        1          0       0      0       0.226   0.170   0       0
bicarb         1          0       0      0       0       0       0       0.390
oathay         1          0.085   2.30   0.620   0.003   0.003   0.758   0.015
Guinehay       1          0.077   2.21   0.600   0       0       0.677   0
milkfresh      1          0.198   0.77   0.276   0.002   0.001   0       0.002
yeast          1          0.097   3.23   0.830   0.002   0.014   0.110   0.018
scanehid       1          0.054   2.04   0.560   0       0       0.614   0
;
********************************************************************************
* Scalars Model
********************************************************************************
SCALARS
cc             Daily Capital cost in percentage based in 1% per month /0.000328768/
dr             Daily Discount rate based in 0.5% montly /0.000164384/
Milkp          Milk price in dollar /0.19/
Milcorn        Milk-corn price ratio for cow price function
Pbeef          Beef price US$ /1.21120/
Plabor         Daily labor cost per cow US$ /0.24/
day            Time period considered /365/
Pland          Land price US$ /824.18/
InvlandM       Fixed Land investment in Milk enterprise  /824.18/
InvlandR       Fixed Land investment in Replacement enterprise /824.18/
pfacil         Cost of facilities per head /646.09/

COUNT          Loop counter /1/
GLOBALMAX      Loop global maximum
;
********************************************************************************
* Declaration of the Model Variables
********************************************************************************
VARIABLES

********************************************************************************
********************************************************************************
* Milk Enterprise (ME) variables
********************************************************************************
qcm(b)         quantity of mature cow in maintenance period
qcl(b)         quantity of mature cow in lactating period
qcp(b)         quantity of mature cow in pregnant period
HpM(b)         Quantity of baby heifers produced in Milk enterprise
HpMmkt(b)      Quantity of baby heifers sold to the mkt
HpMR(b)        Quantity of baby heifers sold to the Replacement enterprise
SpM(b)         Quantity of baby steer produced in Milk enterprise
SpMmkt(b)      Quantity of baby steer sold to the mkt
SpMR(b)        Quantity of baby steer sold to the Replacement enterprise
QheifmktM(b)   Quantity of heifers bought from market
QheifRM(b)     Quantity of heifers bought from Replacement Enterprise
mp(b)          Total milk produced
mbreed(b)      Milk production per cow per day by breed (b)
nmilk(b,n)     Total Required nutrient for milk production by breed (b)
```

nother(b,n)   Total required nutrients for maintenance+pregnance in breed (b)
nutdemM(b,n)   Total nutrient demand in ME
nsupM(b,n)   Total nutrient supply in ME

* Daily quantity of feed 'f' received by individual cows in ME
Qfcownonpr(b,f)   supplied feed 'f' to a nonpregnant cow per day
QfcowLE(b,f)   supplied feed 'f' to a lactating and emputy cow per day
QfcowLP(b,f)   supplied feed 'f' to a lactating and pregnant cow per day
QfcowPD(b,f)   supplied feed 'f' to a pregnant and dry cow per day

* Origen of suplied feed 'f'
QbuymktM(b,f)   Quantity of feed 'f' bougth from mkt
QbuyLM(b,f)   Quantity of feed 'f' bought from LE

* Economic Variables
InvcowM(B)   Milk enterprise investment in mature cow
InvfacilM(b)   Milk Enterprise investment in facilties
InvM(b)   Milk Enterprise investment
fcostM(b)   Feed cost in ME
CcostM(b)   Capital Cost in ME
LcostM(b)   Labor Cost in ME
repcostM(b)   Replaced mature cow cost
MccostM(b)   Medical care cost
OcostM(b)   Other Cost (transport & energy & fuel & maintenance & taxes)
FxcM(b)   Fixed cost
VrcostM(b)   Variable cost
TcostM(b)   Total cost in ME
RevMM(b)   Revenue from milk
RevbM(b)   Revenue from beef in ME
ProfM(b)   Profit in ME
****

****
* Replacement Enterprise (RE) variables
****
*** Heifers production
HpR(b)   Heifers birthed in RE
HpRmkt(b)   Baby heifers birthed in RE and sold to market
HpRR(b)   Baby heifers birthed and Kept in RE
Heif1i(b)   One-year heifers in the beginning of the year
H0buymktR(b)   One-year heifers bought from market
Heif1f(b)   One-year heifers in the ending of the year
H1RR(b)   One-year heifers grew and Kept in RE
H1sout(b)   One-year heifers grew in RE and sold to marktet
Heif2i(b)   Two-years heifs in the beginning of the year
H1buymktR(b)   Two-years heifers bought from market
Heif2f(b)   Two-years heifers in the ending of the year
Habt(b)   Heifers that abort
Qhsout(b)   Two-years heifers sold to the market
heif(b)   Total heifers in the herd

*** Steers production
SpR(b)   Steers birthed in RE
SpRmkt(b)   Steer birthed in RE and sold to market
SpRR(b)   Steer birthed and kept in RE
Steer1i(b)   One-year Steer in the beginning of the year
S0buymktR(b)   One-year Steers bought from market
Steer1f(b)   One-year Steer in the ending of the year
S1RR(b)   One-year steer grew and Kept in RE
S1sout(b)   One-year steer grew in RE and sold to market
Steer2i(b)   Two-years steer in the beginning of the years
S1buymktR(b)   Two-years Steers bought from market

```
Steer2f(b)        Two-years steer in the ending of the year
steer(b)          Total steer in the herd

*** Nutrient requeriements
Hneed(b,n)        Required nutrients for heifer
Sneed(b,n)        Required nutrients for steer
nutdemR(b,n)      Nutrient demand in RE
nsupR(b,n)        Nutrient supplied in RE

* Origen of suplied feed 'f'
QbuymktR(b,f)     Feed 'f' bought from market
QbuyLR(b,f)       Feed 'f' bought from LE

* Daily quantity of feed 'f' received by individual cows in RE
Qfheif1i(b,f)     supplyed feed 'f' to a one-year heifer per day
Qfheif2i(b,f)     supplyed feed 'f' to a two-year heifer per day
Qfsteer1i(b,f)    supplyed feed 'f' to a one-year steer per day
Qfsteer2i(b,f)    supplyed feed 'f' to a two-year steer per day

* Economic variables
InvfacR(b)        Replacement Enterprise investment in facilties
InvR(b)           Replacement Enterprise investment
CcostR(b)         Capital cost in RE
fcostR(b)         Feed cost in RE
LcostR(b)         Labor cost in RE
MccostR(b)        Medical care cost in RE
OcostR(b)         Other Cost (transport & energy & fuel & maintenance & taxes)
repcostR(b)       Replacement cost - equivalent to the amount invested in animals
FxcostR(b)        Fixed cost
VrcostR(b)        Variable cost
TcostR(b)         Total cost in RE
revR(b)           Revenue in RE
profR(b)          Profit in RE
********************************************************************************


********************************************************************************
* Land Enterprise (LE) variables
********************************************************************************
QprodL(b,f)       Quantity of feed 'f' produced
buyland(b)        Quantity of land bought
Qprod1L(b,f,l)    Quantity of feed 'f' produced in land type 'l'
Qprod2L(b,f)      Summation over land type 'l' the amount of feed 'f' produced.
QlandF(b,l)       Proportion of land 'l' in the land bought
InvlandL(b)       Investment in land
fcostL(b)         Feed Production Cost
TcostL(b)         Total cost in LE
TrcostL(b,f)      Transfer cost in LE - Price of feed 'f' sold to ME and RE
revL(b)           Land Enterprise revenue
profL(b)          Land Enterprise profit
********************************************************************************


********************************************************************************
* System Variables
********************************************************************************
qtM(b,f)          Quantity of feed 'f' supplied in MIlk enterprise
qtR(b,f)          Quantity of feed 'f' supplied in Replacement enterprise

* Prices variables
PcowM(b)          Price of mature dairy cow in breed b
Pheif(b)          Price of replacement heifers (2 year female)
```

```
Pheif1(b)        Price of replacementHeifers (1 year female)
Pheif0(b)        Price of baby female calf
Psteer0(b)       Price of baby male calf
Psteer1(b)       Price of male calf first year (1 year old male)
Psteer(b)        Price of male calf ending of the process (2 years old male)

* System Optimiation variables
NetZ(b)          Summation of Milk Repalcement and land Profit
Z                System Profit - variable to be optimized
*********************************************************************************
;


*********************************************************************************
Positive variables
* Milk enterprise positive variables
qcm,qcl,qcp,HpM,HpMmkt,HpMR,SpM,SpMmkt,SpMR,QheifmktM,QheifRM,mp,mbreed,nmilk,
nother,nutdemM,nsupM,Qfcownonpr,QfcowLE,QfcowLP,QfcowPD,QbuymktM,QbuyLM,InvcowM,
InvfacilM,InvM,fcostM,CcostM,LcostM,repcostM,MccostM,OcostM,FxcM,VrcostM,TcostM,
RevMM,RevbM,

* Replacement enterprise positive variables
HpR,HpRmkt,HpRR,Heif1i,H0buymktR,Heif1f,H1RR,H1sout,Heif2i,H1buymktR,Heif2f,Habt,
Qhsout,heif,SpR,SpRmkt,SpRR,Steer1i,S0buymktR,Steer1f,S1RR,S1sout,Steer2i,
S1buymktR,Steer2f,steer,Hneed,Sneed,nutdemR,nsupR,QbuymktR,QbuyLR,Qfheif1i,
Qfheif2i,Qfsteer1i,Qfsteer2i,InvfacR,InvR,CcostR,fcostR,LcostR,MccostR,OcostR,
repcostR,FxcostR,VrcostR,TcostR,revR,

* Land enterprise positive variables
QprodL,buyland,Qprod1L,Qprod2L,QlandF,InvlandL,fcostL,TcostL,TrcostL,revL

*System positive variables
qtM,qtR,PcowM,Pheif,Pheif1,Pheif0,Psteer0,Psteer1,Psteer
*********************************************************************************
;

*********************************************************************************
* Fixing data to met the requirements of Simulation in Constrainted Model
*********************************************************************************
* Small farms
mbreed.fx(bop)=4.1;
InvlandL.fx(b)=33577.09 ;
InvcowM.fx(b)=19279.71;

*********************************************************************************
**Prices
Psteer.fx(b)=w(b)*Pbeef*0.50;
PcowM.lo(b)=Psteer.l(b);
Psteer1.fx(b)=Psteer.l(b)/2;
Psteer0.fx(b)=binws(b)*Pbeef;
Pheif.lo(b)=Psteer.l(b);
Pheif1.fx(b)=Pheif.l(b)/2;
Pheif0.fx(b)=binwh(b)*Pbeef;

Milcorn=Milkp/Mprice('corngrain');

** Start value
QCM.lo(bop)=0.01;
```

```
*******************************************************************************
* Declaration of the Model EQUATIONS
*******************************************************************************

*******************************************************************************
* Milk Enterprise (ME) Equations
*******************************************************************************
Eq_pcowM(b)            Milk cow price function
Eq_qcl(b)              Quantity of cow in lactating period
Eq_qcp(b)              Quantity of cow in pregnat period
Eq_HpM(b)              Quantity of Heifers produced in ME
Eq_HpM1(b)             Destiny of Heifers produced in ME
Eq_SpM(b)              Quantity of Steers produced in ME
Eq_SpM1(b)              Destiny of the of steers produced in ME
Eq_Cowbal(b)           Observe the amount of cow to be replaced
Eq_mp(b)               Total milk produced
Eq_nmilk(b,n)          Required nutrient for milk production
Eq_nother(b,n)         Required nutrients for maintenance+pregnance
Eq_nutdemM(b,n)        Total nutrient demanded in ME
Eq_nsupM(b,n)          Total nutrient Supplied in ME

* feeds required and intake constraint
Eq_Qfnonpr(b,n)        Minimum required nutrient for nonpregnat cow
Eq_QfcowLE(b,n)        Minimum required nutrient for lactating and empuly cow
Eq_QfcowLP(b,n)        Minimum required nutrient for lactating and pregnat cow
Eq_QfcowPD(b,n)        Minimum required nutrient for pregnat and dry cow
Eq_Qfnonpr1(b)         Observe the maximum intake in nonpregnat cow
Eq_QfcowLE1(b)         Observe the maximum intake in lactating and empuly cow
Eq_QfcowLP1(b)         Observe the maximum intake in lactating and pregnat cow
Eq_QfcowPD1(b)         Observe the maximum intake in pregnat and dry cow
Eq_QfeqlM(b,f)         Relate quantity of feed 'f' bought with consumed
Eq_mbreed(b)           Constrain cow productivity with genetic potencial
Eq_nutbalM(b,n)        Balance nutrients supplied and demanded in ME

* Economics Equations
Eq_InvcowM(b)          Investment in cow
Eq_InvfacM(b)          Investment in facilities
Eq_InvM(b)             Total capital investment
Eq_fcostM(b)           Feed cost
Eq_CcostM(b)           Captital cost
Eq_LcostM(b)           Labor cost
Eq_repcM(b)            Replacement cows cost
Eq_MccostM(b)          Medical care cost
Eq_OcostM(b)           Other Cost (transport & energy & fuel & maint. & taxes)
Eq_FxcM(b)             Fixed cost
Eq_VrcM(b)             Variable cost
Eq_TcostM(b)           Total cost
Eq_revMM(b)            ME revenue from milk
Eq_revbM(b)            ME revenue from beef
Eq_profM(b)            ME profit

*******************************************************************************
* Replacement Enterprise (ME) Equations
*******************************************************************************
* heifers
Eq_Pheif(b)            Heifers price
Eq_HpR(b)              Heifers birthed in RE
Eq_HpR1(b)             Destiny of heifers birthed in RE
Eq_heif1i(b)           zero-year heifers in the beginning of the year
Eq_Heif1f(b)           One-year heifers in the ending of the year
Eq_hsold(b)            Destiny of one-year heifer produced
Eq_H1rr1(b)            Proportion of one-year heifer will be pregnant
```

Eq_Heif2i(b)	Two-year heifers in the beginning of the year
Eq_Heif2f(b)	Two-year heifers in the ending of the year
Eq_habt(b)	Quantity of heifers that aborted
Eq_H2bal(b)	Destiny of two-year heifer produced
Eq_hbal(b)	Quantity of Heifers in the herd

*steers

Eq_SpR(b)	Steers birthed in RE
Eq_SpR1(b)	Destiny of Steers birthed in RE
Eq_Str1i(b)	One-year steer in the beginning of the year
Eq_Str1f(b)	One-year steer in the ending of the year
Eq_S1bal(b)	Destiny of one-year steer produced
Eq_Str2i(b)	Two-year steer in the beginning of the year
Eq_Str2f(b)	Two-year steer in the ending of the year
Eq_Sbal(b)	Quantity of steer in the herd

*nutrient requirements

Eq_Hneed(b,n)	Daily required nutrients for heifers
Eq_Sneed(b,n)	Daily required nutrients for steers
Eq_nutdemR(b,n)	Nutrient demanded in RE
Eq_nsupR(b,n)	Nutrient supplied in RE
Eq_nutbalR(b,n)	Balance nutrient supplied and demanded in RE
Eq_QfeqlR(b,f)	Relate quantity of feed 'f' bought with consumed

* feeds required and intake constraint

Eq_Qfhf1i(b,n)	Minimum required nutrient for one-year heifers
Eq_Qfhf2i(b,n)	Minimum required nutrient for two-year heifers
Eq_Qstr1i(b,n)	Minimum required nutrient for one-year steer
Eq_Qstr2i(b,n)	Minimum required nutrient for two-year steer
Eq_Qfhf1i1(b)	Observe the maximum intake in one-year heifers
Eq_Qfhf2i1(b)	Observe the maximum intake in Two-year heifers
Eq_Qstr1i1(b)	Observe the maximum intake in one-year steer
Eq_Qstr2i1(b)	Observe the maximum intake in two-year steer

* Economics Equations

Eq_InvfacR(b)	Investment in facilities in RE
Eq_InvR(b)	Total investment in RE
Eq_CcostR(b)	Captital Cost in RE
Eq_fcostR(b)	Feed cost in RE
Eq_LcostR(b)	Labor Cost in RE
Eq_MccostR(b)	Medical care cost
Eq_OcostR(b)	Other Cost (transport & energy & fuel & maint. & taxes)
Eq_repcR(b)	Replacement cows cost in RE
Eq_FxcR(b)	Fixed cost in RE
Eq_VrcR(b)	Variable cost in RE
Eq_TcostR(b)	Total cost in RE
Eq_revR(b)	Revenue in RE
Eq_profR(b)	Profit in RE

****

*Constrain ureia and poultry-bed

Eq_Ureia(b,m)	Limit the ureia intake in RE
Eq_Ureia1(b,m)	Limit the ureia intake in ME
Eq_poultbed(b,m)	Limit the poultry-bed intake

****

****

* Land Enterprise (ME) Equations

****

Eq_Prodbal(b,p)	Balance production with RE and ME feed demanded
Eq_QProdsh(b,f)	Potential produciton of feed 'f' in land type 'l'

```
Eq_Qprod1L(b,f,l)        feed produced in land type 'l'
Eq_Qprod2L(b,f)          Total feed 'f' produced summed over type 'l'
Eq_Qland(b,l)            Proportion of land 'l' in the land bought
Eq_Qprodeq(b,p)          Observe the quantity of feed 'f' required do be produced

* Economic equations
Eq_Invland(b)            Investment in land in LE
Eq_fcostL(b)             Feed cost in LE
Eq_TrcostL(b,f)          Transfer cost to ME and RE
Eq_TcostL(b)             Total cost in LE
Eq_revL(b)               Revenue in LE
Eq_profL(b)              Profit in LE

********************************************************************************
* Declaration of System Equations
********************************************************************************
Eq_Endow(b)              Observe the investment capacity of farm
Eq_Profit(b)             Profit as a summation of ME RE and LE profit
Eq_NetProf               System profit - OBJECTIVE FUNCTION
********************************************************************************
;

********************************************************************************
* Equations Definitions
********************************************************************************

********************************************************************************
** MILK ENTERPRISE
********************************************************************************
Eq_pcowM(b)..            PcowM(b)=e= IntM(b)+pgp(b)*Mbreed(b)+pmp(b)*Milcorn+
                         Ppbeef(b)*Pbeef+Pint(b)*dr*30*100;
Eq_qcl(b)..              qcl(b)=e=qcm(b)*cint(b);
Eq_qcp(b)..              qcp(b)=e=qcl(b)*fertil(b);

** Heifers steers
Eq_HpM(b)..              HpM(b)=e=(1-abt(b))*qcp(b)/2;
Eq_HpM1(b)..             HpMmkt(b)+HpMR(b)=e=HpM(b);
Eq_SpM(b)..              SpM(b)=e=(1-abt(b))*qcp(b)/2;
Eq_SpM1(b)..             SpMmkt(b)+SpMR(b)=e=SpM(b);
Eq_Cowbal(b)..           QheifmktM(b)+QheifRM(b)=e= qcm(b)*(culling(b)+death(b));

** Milk produciton and required nutrients (DAMAND SIDE)
Eq_mp(b)..               mp(b)=e=mbreed(b)*qcl(b)*305;

Eq_nmilk(b,n)..          nmilk(b,n)=e=Milk3(b,n)*mp(b);
Eq_nother(b,n)..         nother(b,n)=e=Milk1(b,n)*[(qcm(b)-qcp(b))*day+qcp(b)*
                         305]+Milk2(b,n)*220*qcp(b)+Dp(b,n)*60*qcp(b);

Eq_nutdemM(b,n)..        nutdemM(b,n)=e=nother(b,n)+nmilk(b,n);
Eq_nsupM(b,n)..          nsupM(b,n)=e=sum(f,[Qfcownonpr(b,f)*[(qcm(b)-qcl(b))*
                         day+(qcl(b)-qcp(b))*60]+QfcowLE(b,f)*[qcp(b)*85+(qcl(b)
                         -qcp(b))*305]+QfcowLP(b,f)*qcp(b)*220+QfcowPD(b,f)*
                         qcp(b)*60]*fednut(f,n));

Eq_Qfnonpr(b,n)..        sum(f,Qfcownonpr(b,f)*fednut(f,n))=g= Milk1(b,n) ;
Eq_QfcowLE(b,n)..        sum(f,QfcowLE(b,f)*fednut(f,n))=g=Milk1(b,n)+Milk3(b,n)
                         *mbreed(b);
Eq_QfcowLP(b,n)..        sum(f,QfcowLP(b,f)*fednut(f,n))=g=Milk1(b,n)+Milk2(b,n)+
                         Milk3(b,n)*mbreed(b);
Eq_QfcowPD(b,n)..        sum(f,QfcowPD(b,f)*fednut(f,n))=g= DP(b,n);

Eq_Qfnonpr1(b)..         sum(f,Qfcownonpr(b,f)*fednut(f,'dry-matter'))=l=PredintM(b)*1.2;
```

```
Eq_QfcowLE1(b)..          sum(f,QfcowLE(b,f)*fednut(f,'dry-matter'))=l=PredintM(b)*1.2;
Eq_QfcowLP1(b)..          sum(f,QfcowLP(b,f)*fednut(f,'dry-matter'))=l=PredintM(b)*1.2;
Eq_QfcowPD1(b)..          sum(f,QfcowPD(b,f)*fednut(f,'dry-matter'))=l=PredintM(b)*1.2;

Eq_QfeqlM(b,f)..          QbuymktM(b,f)$Mprice(f)+QbuyLM(b,f)$Pcost(f)=g=
                          Qfcownonpr(b,f)*[(qcm(b)-qcl(b))*day+(qcl(b)-qcp(b))*60]
                          +QfcowLE(b,f)*[qcp(b)*85+(qcl(b)-qcp(b))*305]+QfcowLP(b,f)
                          *qcp(b)*220+QfcowPD(b,f)*qcp(b)*60;

** Milk Enterprise balance
Eq_mbreed(b)..            mbreed(b)=l=gp(b);
Eq_nutbalM(b,n)..         nsupM(b,n)=g=nutdemM(b,n);

**Initial capital investment in cows and facilities calculation
Eq_InvcowM(b)..           InvcowM(b)=e=PcowM(b)*qcm(b);
Eq_InvfacM(b)..           InvfacilM(b)=e= Pfacil*qcm(b) ;
Eq_InvM(b)..              InvM(b)=e=InvLandM+InvfacilM(b)+InvcowM(b);

** Cost calculation
Eq_fcostM(b)..            fcostM(b)=e= sum(p,QbuyLM(b,p)*Pcost(p))+sum(m,
                          QbuymktM(b,m)*Mprice(m));
Eq_CcostM(b)..            CcostM(b)=e= InvM(b)*cc*day;
Eq_LcostM(b)..            LcostM(b)=e= qcm(b)*Plabor*day;
Eq_repcM(b)..             repcostM(b)=e=(QheifRM(b)+QheifmktM(b))*Pheif(b)
                          -culling(b)*qcm(b)*Psteer(b);
Eq_MccostM(b)..           MccostM(b)=e= Vetcare(b)*qcm(b);
Eq_OcostM(b)..            OcostM(b)=e= Ocost(b)*qcm(b);
Eq_FxcM(b)..              FxcM(b)=e=CcostM(b)+LcostM(b)+MccostM(b)+OcostM(b)+
                          [fcostM(b) – VrcostM(b)];
Eq_VrcM(b)..              VrcostM(b)=e=fcostM(b)*Milk3(b,'tdn')/(nutsupM(b,'tdn'));
Eq_TcostM(b)..            TcostM(b)=e=FxcM(b)+VrcostM(b);

** Revenue & Profit calculation
Eq_revMM(b)..             revMM(b)=e= mp(b)*milkp;
Eq_revbM(b)..             revbM(b)=e=(HpMR(b)+HpMmkt(b))*Pheif0(b)+(SpMR(b)+
                          SpMmkt(b))*Psteer0(b);
Eq_profM(b)..             profM(b)=e= revMM(b) + revbM(b)- TcostM(b);

******************************************************************************
* REPLACEMENT ENTERPRISE
******************************************************************************

Eq_pheif(b)..             Pheif(b)=e= IntR(b)+pemp(b)*mbreed(b) + pmph(b)*milkp;

**HEIFERS
Eq_HpR(b)..               HpR(b)=e=heif2f(b)*fertil(b)/2;
Eq_HpR1(b)..              HpRmkt(b)+HpRR(b)=e=HpR(b);
Eq_Heif1i(b)..            Heif1i(b)=e=HpMR(b)+HpRR(b)+H0buymktR(b);
Eq_Heif1f(b)..            Heif1f(b)=e=Heif1i(b)*(1-deathH(b));
Eq_hsold(b)..             h1RR(b)+h1sout(b)=e=Heif1f(b);
Eq_H1rr1(b)..             H1rr(b)=l=heif1f(b)*Tadjheif(b);
Eq_Heif2i(b)..            Heif2i(b)=e=H1rr(b)+H1buymktR(b);
Eq_Heif2f(b)..            Heif2f(b)=e=Heif2i(b)*(1-deathH(b)-abt(b));
Eq_Habt(b)..              Habt(b)=e=heif2i(b)*abt(b);
Eq_H2bal(b)..             QheifRM(b)+Qhsout(b)=e=Heif2f(b);
Eq_hbal(b)..              Heif(b)=e= Heif1i(b)+ Heif2i(b);

**STEERS
Eq_SpR(b)..               SpR(b)=e=heif2f(b)*fertil(b)/2;
Eq_SpR1(b)..              SpRmkt(b)+SpRR(b)=e=SpR(b);
Eq_Str1i(b)..             Steer1i(b)=e=SpMR(b)+SpRR(b)+S0buymktR(b);
Eq_Str1f(b)..             Steer1f(b)=e=Steer1i(b)*(1-deathS(b));
```

```
Eq_S1bal(b)..            S1RR(b)+S1sout(b)=e=Steer1f(b);
Eq_Str2i(b)..            Steer2i(b)=e=S1RR(b)+S1buymktR(b);
Eq_Str2f(b)..            Steer2f(b)=e=Steer2i(b)*(1-deathS(b));
Eq_Sbal(b)..             Steer(b)=e=steer1i(b)+steer2i(b);

** Heifer and steer required nutrient calculation (DEMAND SIDE)
** Heifer demand
Eq_Hneed(b,n)..          Hneed(b,n)=e= Heif1i(b)*Theif0(b,n)+Heif2i(b)*Theif1(b,n);
** steer demand
Eq_Sneed(b,n)..          Sneed(b,n)=e=Steer1i(b)*Tsteer0(b,n)+Steer2i(b)*Tsteer1(b,n);

**Total demand
Eq_nutdemR(b,n)..        nutdemR(b,n)=e=(Hneed(b,n) + Sneed(b,n))*day;

** Feed and nutrients supplied  (SUPPLY SIDE)
Eq_nsupR(b,n)..          nsupR(b,n)=e= sum(f,[Qfheif1i(b,f)*heif1i(b)+
                         Qfheif2i(b,f)*heif2i(b)+ Qfsteer1i(b,f)*Steer1i(b)+
                         Qfsteer2i(b,f)*Steer2i(b)]*day*fednut(f,n));

Eq_nutbalR(b,n)..        nsupR(b,n)=g=nutdemR(b,n);
Eq_QfeqlR(b,f)..         QbuymktR(b,f)$Mprice(f)+ QbuyLR(b,f)$Pcost(f)=g=
                         [Qfheif1i(b,f)*heif1i(b)+ Qfheif2i(b,f)*heif2i(b)+
                         Qfsteer1i(b,f)*Steer1i(b)+Qfsteer2i(b,f)*Steer2i(b)]*day;
Eq_Qfhf1i(b,n)..         sum(f,Qfheif1i(b,f)*fednut(f,n))=g= Theif0(b,n);
Eq_Qfhf2i(b,n)..         sum(f,Qfheif2i(b,f)*fednut(f,n))=g= Theif1(b,n);
Eq_Qstr1i(b,n)..         sum(f,Qfsteer1i(b,f)*fednut(f,n))=g=Tsteer0(b,n);
Eq_Qstr2i(b,n)..         sum(f,Qfsteer2i(b,f)*fednut(f,n))=g=Tsteer1(b,n);
Eq_Qfhf1i1(b)..          sum(f,Qfheif1i(b,f)*fednut(f,'dry-matter'))=l=Preheif0(b)*1.2;
Eq_Qfhf2i1(b)..          sum(f,Qfheif2i(b,f)*fednut(f,'dry-matter'))=l=Preheif1(b)*1.2;
Eq_Qstr1i1(b)..          sum(f,Qfsteer1i(b,f)*fednut(f,'dry-matter'))=l=Presteer0(b)*1.2;
Eq_Qstr2i1(b)..          sum(f,Qfsteer2i(b,f)*fednut(f,'dry-matter'))=l=Presteer1(b)*1.2;

** Economic equations
Eq_InvfacR(b)..          InvfacR(b)=e= pfacil*(heif(b)+ steer(b)) ;
Eq_InvR(b)..             InvR(b)=e=InvLandR + InvfacR(b) + RepcostR(b);

** Feed & capital & labor & Medical care cost calculation
Eq_CcostR(b)..           CcostR(b)=e= InvR(b)*cc*day;
Eq_fcostR(b)..           FcostR(b)=e= sum(p,QbuyLR(b,p)*Pcost(p))+sum(m, QbuymktR(b,m)*
                         Mprice(m));
Eq_LcostR(b)..           LcostR(b)=e= (heif(b)+steer(b))*Plabor*day;
Eq_MccostR(b)..          MccostR(b)=e= Vetcare(b)*(heif(b)+steer(b));
Eq_OcostR(b)..           OcostR(b)=e= Ocost(b)*(heif(b)+steer(b));
Eq_repcR(b)..            RepcostR(b)=e=(H0buymktR(b)+HpMR(b))*Pheif0(b)+(S0buymktR(b)+
                         SpMR(b))*Psteer0(b)+H1buymktR(b)*Pheif1(b)+S1buymktR(b)*
                         Psteer1(b);
Eq_FxcR(b)..             FxcostR(b)=e=CcostR(b)+RepcostR(b);
Eq_VrcR(b)..             VrcostR(b)=e=FcostR(b)+MccostR(b)+OcostR(b)+LcostR(b);
Eq_TcostR(b)..           TcostR(B)=e= FxcostR(b)+VrcostR(b);

** Revenue & Profit calculation
Eq_revR(b)..             revR(b)=e= QheifRM(b)*Pheif(b)+(Qhsout(b)+Habt(b)+steer2f(b))*
                         Psteer(b)+ h1sout(b)*Pheif1(b)+HpRmkt(b)*Pheif0(b)+S1sout(b)*
                         Psteer1(b)+SpRmkt(b)*Psteer0(b);
Eq_profR(b)..            profR(b)=e= revR(b) - TcostR(b);
**********************************************************************************

** Ureia and poultry-bed constraint
Eq_Ureia(b,m)..          QbuymktR(b,'ureia')=l=0.01*nsupR(b,'dry-matter') ;
Eq_Ureia1(b,m)..         QbuymktM(b,'ureia')=l=0.01*nsupM(b,'dry-matter');
Eq_poultbed(b,m)..       QbuymktR(b,'poult_bed')+QbuymktM(b,'poult_bed')=l=0.01*
                         nsupR(b,'dry-matter')+nsupM(b,'dry-matter');
```

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*******************************************************************************


*******************************************************************************
* LAND ENTERPRISE
*******************************************************************************
Eq_Prodbal(b,p)..        QprodL(b,p)=e= QbuyLM(b,p)+QbuyLR(b,p);
Eq_QProdsh(b,p)..        buyland(b)*sum(l, Tland(p,l)*landprop(l)*avp(p)
                         *day)=g=QprodL(b,p);
Eq_Qprod1L(b,p,l)..      Qprod1L(b,p,l)=l= QlandF(b,l)*Tland(p,l)*avp(p)*day;
Eq_Qprod2L(b,p)..        Qprod2L(b,p)=e=sum(l,Qprod1L(b,p,l));
Eq_Qland(b,l)..          QlandF(b,l)=e=buyland(b)*landprop(l);
Eq_Qprodeq(b,p)..        Qprod2L(b,P)=g=QprodL(b,p);
Eq_Invland(b)..          InvlandL(b)=e=buyland(b)*Pland;
Eq_fcostL(b)..           FcostL(b)=e=sum(p, Qprod2L(b,p)*Pcost(p));
Eq_TcostL(b)..           TcostL(b)=e= FcostL(b);
Eq_TrcostL(b,p)..        TrcostL(b,p)=e= Pcost(p);
Eq_revL(b)..             revL(b)=e=sum(p,(QbuyLM(b,p)+QbuyLR(b,p))*Pcost(p));
Eq_profL(b)..            profL(b)=e=revL(b)-TcostL(b) ;
*******************************************************************************


*******************************************************************************
* SYSTEM EQUATIONS
*******************************************************************************
* Endowment value or investment capacity
Eq_Endow(b)..            InvM(b)+InvR(b)+InvLandL(b)=e=Endow(b);

** Profit System calculation
Eq_Profit(bop)..         Netz(bop)=e=(profM(bop)+profR(bop)+ProfL(bop))/(1+(dr*day));
Eq_Netprof(bop)..        Z=e= netz(bop);
*******************************************************************************

Model bms  /all/;
solve bms using nlp maximizing z ;
```

VITA

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