2012

The Economic Impact of the New Insensitive Sorghum Cultivars in the Dairy Market of Nicaragua

Gabriel Garcia Gomez
Purdue University

Graduate School ETD Form 9
(Revised 12/07)

PURDUE UNIVERSITY
GRADUATE SCHOOL
Thesis/Dissertation Acceptance

This is to certify that the thesis/dissertation prepared

By Gabriel Garcia Gomez

Entitled The Economic Impact of The New Insensitive Sorghum Cultivars in The Dairy Market of Nicaragua

For the degree of Master of Science

Is approved by the final examining committee:

John Sanders
Chair

John Lee

Juan Sesmero

To the best of my knowledge and as understood by the student in the *Research Integrity and Copyright Disclaimer (Graduate School Form 20)*, this thesis/dissertation adheres to the provisions of Purdue University's "Policy on Integrity in Research" and the use of copyrighted material.

Approved by Major Professor(s): John Sanders

Approved by: Gerald Shively 06/29/2012
Head of the Graduate Program Date

Graduate School Form 20
(Revised 9/10)

PURDUE UNIVERSITY
GRADUATE SCHOOL

Research Integrity and Copyright Disclaimer

Title of Thesis/Dissertation:

The Economic Impact of The New Insensitive Sorghum Cultivars in The Dairy Market of Nicaragua

For the degree of Master of Science

I certify that in the preparation of this thesis, I have observed the provisions of *Purdue University Executive Memorandum No. C-22,* September 6, 1991, *Policy on Integrity in Research.**

Further, I certify that this work is free of plagiarism and all materials appearing in this thesis/dissertation have been properly quoted and attributed.

I certify that all copyrighted material incorporated into this thesis/dissertation is in compliance with the United States' copyright law and that I have received written permission from the copyright owners for my use of their work, which is beyond the scope of the law. I agree to indemnify and save harmless Purdue University from any and all claims that may be asserted or that may arise from any copyright violation.

Gabriel Garcia Gomez

Printed Name and Signature of Candidate

06/29/2012

Date (month/day/year)

*Located at http://www.purdue.edu/policies/pages/teach_res_outreach/c_22.html

THE ECONOMIC IMPACT OF THE NEW INSENSITIVE SORGHUM CULTIVARS IN THE DAIRY MARKET OF NICARAGUA

A Thesis

Submitted to the Faculty

of

Purdue University

by

Gabriel Garcia Gomez

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

August 2012

Purdue University

West Lafayette, Indiana

ACKNOWLEDGEMENTS

I would like to thank to God for giving me health and life. I also would like to thank my Major Professors John Sanders for the opportunity to work on this research and for giving me the financial support.

I also want to thank Rafael Obando and his research team in INTA-Nicaragua. It would not be possible to do this research without their support.

I extend my gratitude to the staff of the Department of Agricultural Economics for their support throughout this program.

Finally, thanks to all my friends that always share information and knowledge.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Garcia Gomez, Gabriel. M.S., Purdue University, August 2012. The Economic Impact of the New Insensitive Sorghum Cultivars in the Dairy Market of Nicaragua. Major Professor: John Sanders.

This thesis estimates the benefits and returns to consumers, processors, producers and society of the new insensitive sorghum cultivars used for the dairy production in Nicaraguan. Many dairy producers also sell their grain so sorghum production is a multi-product activity.

The breeding project of INTA developed cultivars for simultaneous use in dairy and grain production. Its first release was Pinolero-1 developed during the Nicaraguan civil war. This cultivar was rapidly adopted by farmers after the end of the war in 1990. Subsequently, five more new cultivars have been released. We consider their combined effects.

Through field surveys, we calculated the average cost reduction of milk and grain at the farm level by comparing the cost of farms with and without the new technology. To estimate the aggregate returns, we used an economic surplus model. We estimated the benefits in the dairy and grain market individually. Then we combine benefits in both markets and estimated the total rate of return. The rate of return to dairy alone was 20% and to the associated grain production 12%. We found that the social rate of return of the insensitive sorghum cultivars for combined dairy-grain production in Nicaragua is 16%. In terms of equity, we found that the main beneficiaries are consumers. Small and medium farms obtain important benefits in the grain market while benefits in the dairy market are concentrated on large farms.

Nicaragua is still in the initial stage of dairy development. The higher social returns to dairy and the recent release of a number of new cultivars indicate that there will

probably be an increasing specialization in dairy. Even higher returns are expected. An increase in milk prices from expanding demand will create incentives for producers to shift to more developed dairy systems. This modernization of dairy sector will be undertaken principally by larger farmers but the principal beneficiary will be consumers. Policies, such as milk price control will slow down this modernization and are expected to reduce these potential large benefits to consumers.

CHAPTER 1. INTRODUCTION

1.1. Introduction

Agriculture accounts for 28% of Nicaragua's GDP and employs 31% of its labor force (Banco Central de Nicaragua, 2010). Improving the productivity of the agricultural sector is crucial for Nicaraguan economic growth, food security, and poverty reduction objectives. Increase in output and efficiency can be accomplished through research that results in improved technologies. Agricultural research is a strategic activity to improve productivity and efficiency.

Agricultural research in sorghum began in the mid-1980s by the Nicaraguan Institute of Agricultural Technology (INTA). The new technological innovations are intended to increase yields of various types of sorghums. Public institutions undertake most of the agricultural research since it is difficult for the private sector to capture all the benefits of their research. Hence, private firms tend to under invest in research from a social perspective.

The breeding project of INTA produced cultivars for use in diary and grain production with higher quantity and quality of grain and forage, and often with tolerance to drought and diseases. INTA introduced new cultivars of sorghum and undertook adaptive agronomic research to make this technology available for local environmental condition through field experiments and selection. New cultivars were developed and propagated around the country. The cultivars of insensitive sorghums released were Pinolero (1986[1]), Tortillero Precoz (1990) CNIA (2001), Sorgo Mejor (2007), Forrajero (2010), RCV (2010). Except Pinolero-1 and Tortillero Precoz, the releases were in the last decade.

[1] Release year of the cultivar.

Impact studies are an important source of information to evaluate the progress of the research projects. Additionally, impact research provides policy makers, scientists, and donors with evidence of agricultural research importance to support future funding decisions. This is the first impact study on the insensitive sorghums for dairy-grain production in Nicaragua.

1.2 The Problem

Agricultural research requires scarce resources. Developing countries attempt to allocate their funds to the highest payoff projects. It is necessary to quantify the returns to public research in order to evaluate the investment and their impacts on different components of the society. The problem of this thesis is to determine the returns to agricultural research for the new insensitive sorghum cultivars used in dairy-grain production in Nicaragua. We are also concerned with the distribution of the gains between consumers and producers.

1.3 Objectives

This thesis has the following objectives:

1) Describe the types of farms by size, technology, and system.
2) Estimate the returns to society from the new insensitive sorghum cultivars in the dairy and the grain market.
3) Separate the benefits between consumers, producers, and processors. Separate the benefits between farms by size.
4) Show the variation in the above estimates to various critical economic parameters.
5) Make policy recommendations and research suggestions.

1.4 Methodology

Methodology consists in two parts. The first part estimates the farm level cost reduction effect of the new technology for the combined dairy-grain production. For dairy, we determine the cost reduction by comparing the cost of feed production between users and nonusers of the new technology.[2] For grain, we estimate the grain cost reduction by comparing the production cost of grain between maize and sorghum producers. We calculate the cost of milk and grain from data collected through surveys in the study region. In the second part, we develop a model to estimate the aggregate impact and the rate of return of research for the new insensitive sorghum cultivars in the dairy-grain markets.

1.5 Organization of the Study

This thesis has eight chapters. In chapter two we will delimit the study region and describe our sampling method. Chapter three will discuss income growth and milk consumption. Then we will treat the sorghum and dairy production in Nicaragua. In chapter four, we estimate the milk and grain cost reduction derived from the adoption of the new technology at the farm level. Then in chapter five we will describe the economic surplus model developing the graphic and algebraic expressions of the model to extend the analysis to the macro level. Chapter six will present the results of the model. The sensitivity analysis with alternative elasticities of supply and demand will be in the subject of chapter seven. The final chapter will present the study implications and policy recommendations for INTA, Nicaraguan policy makers, and researchers.

[2] Users of the new technology are dairy farmers with the new insensitive sorghums technology. Non-users are the dairy farmers without sorghum technology.

CHAPTER 2. STUDY REGION

There are three main zones in Nicaragua: the Pacific Region with annual rainfall between 1000 to 2000 mm; the North and Central Regions with annual rainfall between 800 millimeter in the mountain valleys and 2500 millimeters in the eastern hills; the Atlantic Autonomous Regions with annual rainfall from 2500 millimeters to 5000 mm. The Pacific fertile plains surrounding the Lake Managua and Lake Nicaragua are the center of the Nicaraguan agricultural production (INETER, 2005).

This study focuses on the lowlands plains on the Pacific and on the Central Region (Figure 1). We concentrate on 9 departments located in the North Pacific, South Pacific and Central Region of Nicaragua. These departments are the center of dairy production in the country. Principal crops produced in this region are corn, rice, sorghum, sugar cane, and sesame.

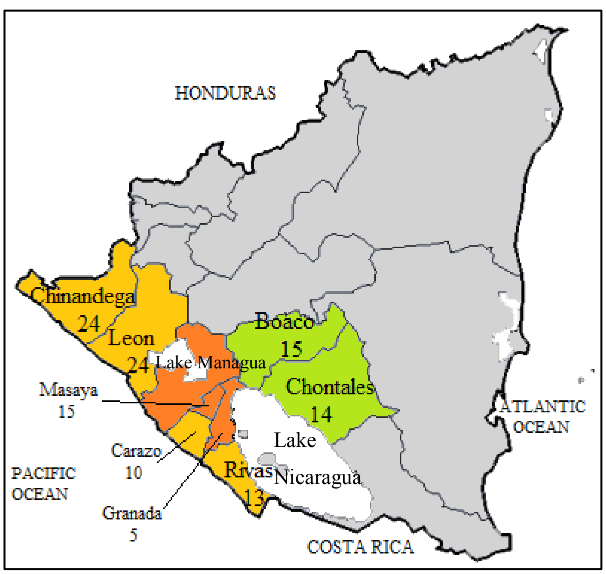

Figure 1. Map of the Study Region.

Source: PROCIG, 2012.

We interviewed 120 dairy farms in the 9 departments indicated above between May and July of 2011. The sampling methodology consisted of two stages. First, we surveyed dairy farms that were beneficiaries of INTA's extension program with dairy and sorghum production. In the second stage, we surveyed dairy farms in the same region as the adopters' farms but not participating in this program. These farms may or not be using sorghum technologies.

In total, 30% (36 farms) of the samples were farms with sorghum technology and INTA extension support. All of these farms were sorghum and dairy producers. The other 70% (84 farms) were farms without INTA's extension service and that were located near by the 30% of the farms getting INTA support. Among these dairy farms, 38 adopted the sorghum technology and 46 did not. Overall, there were 74 farms with sorghum technology and 46 farms without this technology (Table 1). Then we calculated feed costs with and without the new technologies. Clearly, there is a bias in the selection method of the 30% towards INTA's extension beneficiaries.

Table 1. Sample Size

Department	Samples	Adopters	Non-adopters
Boaco	15	11	4
Carazo	10	8	2
Chinandega	24	12	12
Chontales	14	9	5
Granada	5	5	0
Leon	24	19	5
Masaya	15	2	13
Rivas	13	8	5
Total	120	74	46

Source: Survey data 2011.

CHAPTER 3. BACKGROUND

This chapter first considers the increase of milk consumption and its relationship with GDP growth. Then we discuss the sorghum production, types of sorghum, and the new insensitive sorghums. Thirdly we explain the characteristic of dairy production, farm sizes, and the milk supply chain. Finally we discuss the stages of dairy production in Nicaragua.

3.1 Income Growth and Milk Consumption

The World Bank classifies Nicaragua as a lower-middle-income[3] country. Nicaraguan GDP per capita is increasing at 3.7%[4] annually since 1990 (Banco Central de Nicaragua, 2009).

From 2002 to 2007 the per capita income increased 5.1 % per year, while the milk supply annual increase was 1.5% (Figure 2). Milk consumption has doubled between 1990 and 2010 from 30 to nearly 60 kilograms per capita per year. There is a substantial increase in 1998 apparently due to food donations after Hurricane Mitch.

---

[3] This income category is for countries with a GDP per capita (PPP) between $1006 and $3976 (World Bank Data, 2011).

[4] Compound growth.

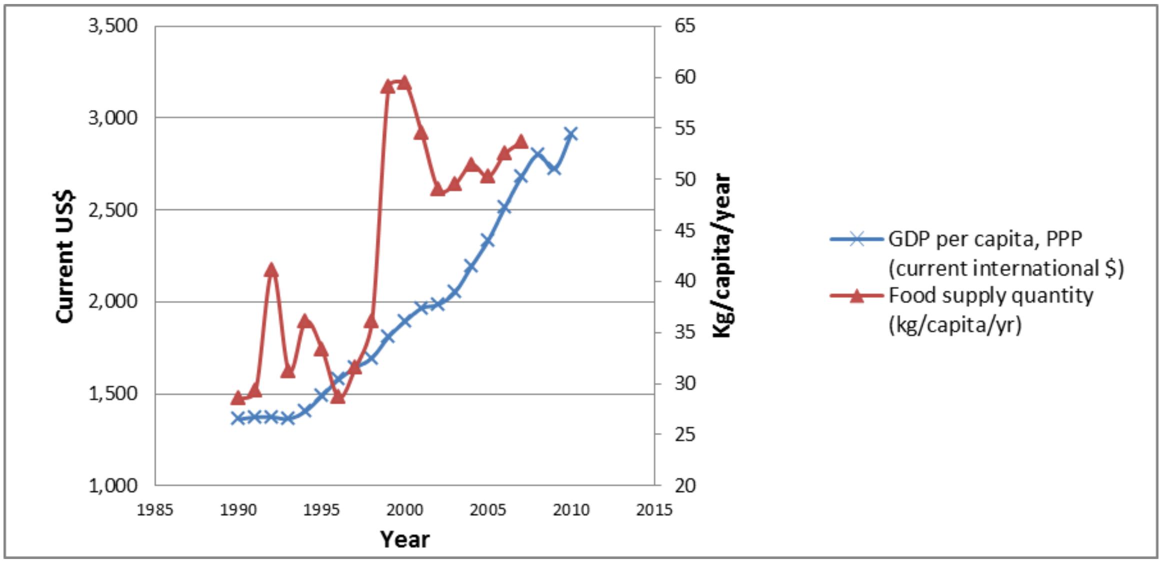

Figure 2. Evolution of the GDP (PPP) and Milk Supply.

Source: FAO Statistics, 2010; World Bank Data, 2011.

3.2 Sorghum Production in Nicaragua

In Nicaragua, sorghum (*Sorghum bicolor*) is second in importance after maize in the quantity produced and the area cultivated. Its grain and forage are particularly useful for livestock, swine, and poultry production, as well as reserve cereal for human consumption when the maize harvest fails (Gutierrez, 2004, p. 1). In contrast with maize, sorghum can remain dormant during periods of drought and continue growing when it rains again. The composition of maize and sorghum forage is similar. Although maize provides higher levels of crude protein and lower content of crude fiber, maize production costs are higher than that of sorghum due to the ability to make multiple cuts of sorghum (Estebez & Clara, 2010).

There are three types of sorghum in Nicaragua: the industrial sorghums, the native light sensitive sorghums, and the light insensitive white sorghums (Gutierrez, 2004, p. 1).

The industrial sorghums generally have red grain and often have tannin. The poultry industry uses this sorghum to make concentrate. Large farms grow this sorghum under mechanized systems in the Pacific coast plains of Nicaragua. Red sorghums are not used in dairy production.

The native sensitive sorghums "Millon" are grown by many small farmers in "primera" [5] the first growing season in association with maize on the hillsides. The sensitivity to light insures that sorghums will not compete with maize but waits its turn for the light when the maize stalks are broken during the "canicula". These sorghums are cultivated on 25 thousand hectares, and have an average yield of 1.4 ton of grain per hectare (Valdivia, 2010, p. 1). Farmers fertilize the maize in "primera" and sorghum benefits in "postrera" when it has the sunlight. Native sensitive sorghums require about 180 to 210 days to mature. This sorghum serves as a reserve food when maize harvests are deficient and as a feed for their livestock when maize harvests are adequate.

White insensitive[6] sorghums are planted in "postrera" the second part of the growing season.[7] White sorghums are generally of intermediate height with the exception of the tall Pinolero-1and Tortillero Precoz. This intermediate stature makes mechanical harvesting easy. Small and medium farms use sorghum grain as feed for animals and sorghum stalks as forage. Large farmers use sorghum grain to make homemade concentrate or use the whole plant to make silage.

Because of their considerable potential for high yields and their fit into the "postrera" period, the Nicaraguan sorghum breeding program for dairy- grain production has focused on the insensitive white sorghums. INTA has released six new varieties of insensitive sorghums since 1986.

These new sorghum cultivars are adapted to the environmental conditions of the Pacific plains in Nicaragua. These sorghums are also tolerant to common sorghum diseases including anthracnose, dry stem rot, and grey leaf spot. The agronomic features and year of release of the new insensitive sorghum cultivars are shown in table 2.

---

[5]The Nicaraguan Agricultural year begins in May and ends in December. It has two rainy periods and a dry interval. The first rainy periods is 3 months long and is known as "primera". After that, there is a dry interval that last for approximately two weeks and is known as "canicula". The second rainy period is 3 months long and is called "postrera".

[6]Photo-insensitive varieties are those whose flowering is not affected by the amount of daylight hours and flower regardless of the time they are planted. Insensitive sorghums initiate flowerings under any length of night hours and plants are called insensitive to photoperiod (Gutierrez, 2004, p. 3).

[7] Planting is recommended from August 10th to September 7th so that the grain maturation and harvest coincides with the beginning of the dry season. This reduces the loss from late rains bringing the mold-insect complex.

Table 2. New Insensitive Sorghum Cultivars.

Cultivar	Year of release	Grain Yield (Tons/Ha)	Green Material Yield (Tons/Ha)	Dry Material Yield (Tons/ha)	Harvest Maturity Period (days)
Pinolero-1	1986	4.5	30	10	110
INTA-CENIA	2001	5	25	8	110
INTA-Tortillero Precoz	1990	3.2	25	8	95
INTA- Sorgo Mejor	2007	4.5	27	9	100
INTA- RCV	2010	4.5	27	9	115
INTA-Forrajero	2010	-	40	13	45

Source: INTA, 2010.

On experimental fields farmers have grain yields between 3.2 and 4.5 tons/ha with these new cultivar (Table 2). These yields are substantially higher than the 1.4 tons/ha of the native sensitive sorghums. Moreover, these new sorghum cultivars have excellent grain and forage quality. New insensitive sorghums have been adopted by small, medium and large farmers especially in the Pacific departments of Nicaragua. Insensitive sorghum area for principally for dairy with production estimated to be divided approximately with 30% on small farms, 30% on medium farms, and 40% on large farms (Obando, 2011).

Rapid adoption of Pinolero-1 began in 1990 after the end of the civil war (Figure 3). By 2000 Pinolero-1 area reached its maximum at 5,500 hectares. Tortillero Precoz was released in 1990. By 2010 there were about 1,000 hectares planted to this cultivar. After the successful introduction of Pinolero-1 and Tortillero Precoz, large dairy farmers in the Pacific coast asked for shorter cultivars to facilitate mechanization. Consequently, breeders developed shorter cultivars starting with the release of INTA-CNIA in 2001. Pinolero-1 has been substituted with INTA-CNIA especially on medium and large dairy farms. Currently, farmers plant INTA-CNIA on approximately 5,000 hectares. The newest sorghum cultivars RCV, Sorgo Mejor, and Forrajero were released very recently and their adoption levels are still low. However, planted areas for these new cultivars are expected to increase rapidly in the next decade (Obando, 2011).

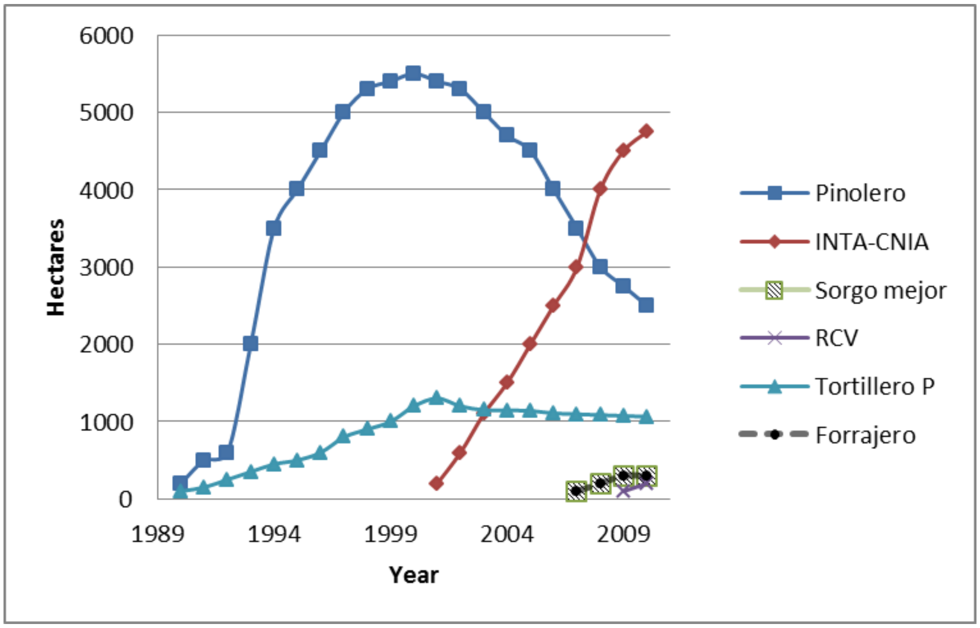

Figure 3. Planted Areas of the New Insensitive Sorghums for Dairy.

Source: Estimates from Gutierrez, Obando, and Vargas, 2011.

The new insensitive sorghum cultivars are particularly important for feeding dairy livestock in the dry summer period. During the summer farmers face a lack of animal feedstuff and poor nutrient value of forages.[8] A sufficient amount of nutrients reduces livestock mortality, increases milk production, and extends the milking period (INTA, 2011, p. 2).Dairy farms can use sorghum forage as stubble[9], hay[10], silage, and grain for concentrate.[11] Use of sorghum for silage is just beginning especially on large farms in Nicaragua with 7 observations in the sample.[12]

The use of sorghum reduces costs of milk production by reducing the need for commercial concentrate[13] and improved pastures. Insensitive sorghum also can reduce

[8] The dry season begins in December and ends in May. The critical period for feed availability is between March and May.

[9] Sorghum stalks left in the ground when the crop is cut, locally known as “Rastrojo de Sorgo”

[10] Sorghum stalk cut and dried for use as forage, locally known as “Guate de Sorgo”

[11] A Typical homemade concentrate would contain around 43% of milled sorghum grain mixed with urea, molasses, and chicken manure. This would have a raw protein content of 19.5%. The average ration is about 3 to 4 pounds per day per cow (INTA, 2011).

[12] In El Salvador silage production predominates on medium and large farms and is associated with the high productivity in dairy production.

[13] Commercial concentrate is produced by large animal food corporations.

the feeding cost because of its multi-cut feature. Another advantage of insensitive sorghum over other crops, such as maize, is its tolerance to drought. In some dry zones of Nicaragua maize is not an option.

The use of sorghum grain varies with farm size (Table 3) as farm size increases farmers prefer to use sorghum grain to feed their dairy cows rather than selling or feeding other farm animals. Medium and small farms primarily sell sorghum grain. These farms also allocate an important percentage for on-farm consumption.[14] Small farmers only use 8% of their sorghum for dairy. In contrast, large farms use 80% of their sorghum to feed dairy cows. They only sell 20% of the harvested grain.

Table 3. Sorghum Grain Uses per Farm Size

Concept	Small	Medium	Large
Dairy Feeding	8%	11%	80%
Farm Sales	61%	68%	20%
On farm	31%	22%	-
Poultry	21%	14%	-
Swine	7%	6%	-
Human	3%	2%	-

Source: Author's calculations from survey data 2011

3.3 Dairy Production in Nicaragua

Dairy production in Nicaragua was 753 thousand tons of milk in 2010. The average yield of milk per cow was 0.7 tons per year. This production is approximately half that of the neighboring countries (FAO Statistics, 2010). Nicaraguan milk production has increased by 20% from 614 thousand tons to 753 thousand tons from 2005 to 2010 (Banco Central de Nicaragua, 2012). Almost 95% of the Nicaraguan dairy farms operate under a dual purpose system[15] producing both milk and beef (MAGFOR, 2008, p. 17).

[14] On-farm consumption is the harvested grain utilized for human, swine, and poultry feeding. On-farm consumption does not include grain used to feed dairy cows or seed as these are treated as costs to dairy and grain production in this analysis.

[15] This system is common in many developing countries in Latin America. Milking is done once a day and the main sources of feed are pastures or fiber-rich crops byproducts. There is minimal use of supplements (Restrepo, Murgeitio, & Preston, 1991) .

Nicaragua dairy production relies heavily on grazing. The dairy production process is extensive rather than intensive. Use of concentrates and silage is low. Nicaragua has done little extension to increase dairy production as compared to other Central American countries. In Nicaragua, the most popular dairy products are whole milk, dry cheese, and cream cheese. Consumers can purchase these products in local markets or large retail stores.

Small dairy farms have from 1 to 10 cows in production[16] (Table 4). These farms own 26% of livestock and produce 29% of the milk. Medium farms have from 11 to 25 cows in production. These farms own 41% of livestock and produce 44% of the milk. Large farms have more than 25 cows in production. These farms own 33% of livestock and produce 27% of milk in Nicaragua.

Table 4. Farm Size in Nicaragua

Farm Category	Farm Area (Ha)	Cows in Production	Number of farms	Livestock	Milk Production
Small	0.35-35	1 to 10	67%	26%	29%
Medium	35.1-140	11 to 25	27%	41%	44%
Large	>140	>25	6%	33%	27%
Total			100.0%	100.0%	100.0%

Source: IICA, 2005, p. 33; MAGFOR, 2008, p. 27.

The Nicaraguan milk supply chain involves dairy farms, intermediaries, collection centers, semi-industrial plants, industrial plants, and processors. Dairy farmers sell the milk directly to rural intermediaries, collection centers or use it for home consumption. Rural milk collectors are intermediaries whose primary purpose is the transportation of milk from farms to the collection centers. Some farmers are large enough to transports their own milk. Milk collection centers gather the milk from farmers and collectors. They put it in cold storage tanks. Then these centers sell the milk to processing plants. Collection center location depends on access to electricity, water, and proximity to milk production regions. There are 107 collection centers with an installed capacity of 598 tons of milk per day (MAGFOR, 2008, p. 20).

[16] This indicator refers to the average of cows milked each day (Cordero, 2011, p. 11).

There are three levels of milk processing: (a) the large industrial plants, (b) the semi-industrial plants, and (c) own farm use of dairy farmers or sale to small artisanal cheese makers.

(a)The large industrial plants belong to PROLACSA, NILAC, CENTROLAC, El Eskimo, and La Exquisita. These plants make pasteurized milk, ice cream, dry milk powder, and yogurt on a large scale. This sector processes approximately 15 % of the total Nicaraguan dairy production. (b) Cooperatives and private societies own the semi-industrial plants. This sector produces pasteurized milk, cheese, cream, butter, and other milk products. The semi-industrial plant sector processes 6% of the milk production. The average percentage of the milk processed into pasteurized products is 21%. This pasteurized milk is the milk processed by large industrial plants and semi-industrial plants. (c) The remainder 79% of the national milk production is utilized by small artisanal cheese makers and by the dairy farmers for their own use or local sales (MAGFOR, 2008, p. 21).

Table 5 indicates the milk prices between farms and the dairy processing plant in the milk supply chain. There is a $50 transportation cost per ton between dairy farms and milk collection centers. This is a 19% margin for transportation. The price of milk for the processing plant is $400 per ton of milk. This implies that even before the milk is pasteurized there is a margin of $135 between the farm and processing plant.

Table 5. Farm, Collection, and Industrial Plant Milk Prices

Concept	Average Price (US$/Ton)
Farm gate price	265
Transportation cost	50
Collection center gate price	315
Collection center margin	30
Collection center price	345
Transportation cost	55
Price at industrial plant Gate	400

Source: MAGFOR, 2008, pp. 19,21.

Figure 4 displays the farm prices, consumer prices, and retail margin from 1995 to 2010.[17] Between 1995 and 2001 the retail margin decreased from 100% to 60%. This is undoubtedly the effect of improved transportation and communication after the civil war. After 2001 the retail margin increased from 70% to 160% between 2002 and 2008. Apparently processors made plant investments to augment processing capacity resulting in an increase in the price of pasteurized dairy products. In the last three years, retail margin declined by approximately 40%. In 2006, the new populist Nicaraguan government implemented programs to reduce staple food prices through price control policies. Moreover, the entry of cooperative dairy producers processing their own milk production also puts downward pressure on margins of the big industrial firms.

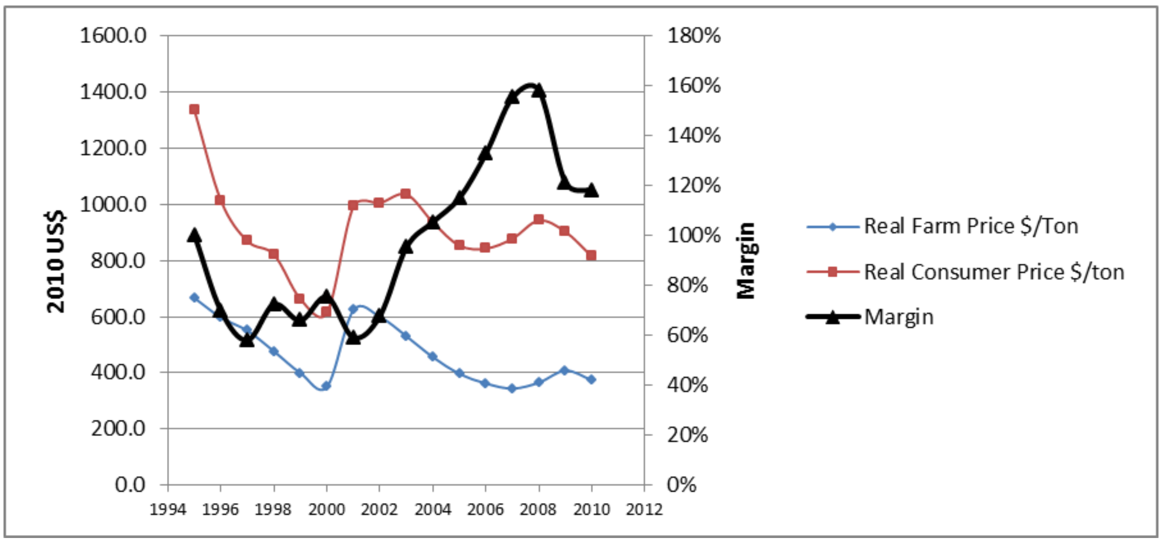

Figure 4. Milk Retail Margin, Farm and Consumer Milk Prices.
Source: FAO, 2009; INIDE, 2010.

Between 1995 and 2010, the average retail margin between farm milk prices and consumer prices was 98%. This margin is applicable only to the pasteurized milk that is processed by industrial and semi-industrial dairy plants. Previously we pointed out that these processors together use 21% of the total milk production. The unpasteurized milk of

[17] Farm price is the price of a ton of raw milk at the farm gate. The consumer price is the price of a ton of pasteurized milk at the retail store.

the rest of the sector has a 19%[18] margin for transportation costs. The different margins will be used to calculate the weighted retail price of milk for the multi-stage surplus model to be developed in Chapter 5.

3.4. Stages of Dairy Production

In Nicaragua, dairy farms are starting to evolve from a traditional extensive production to a developed intensive system. This development process is divided into three stages.

The first stage, also known as the traditional production, combines dairy and agricultural production. In this stage, the dairy cattle diet consists primarily of pastures and forages. Additionally, farmers feed their cows with agricultural byproducts such as stubble of sorghum, maize, or rice. They also collect the stalks to make hay. The feedstuff used by these farms does not have enough protein content. Hence, milk productivity per cow is very low. Farmers feeding costs are low because they use natural pastures, forages, and agricultural byproducts that are relatively low-cost. Most of small and medium dairy farms in Nicaragua are in this first stage. At this level, sorghum is used for dual purpose grain and forage. Grain, which is high in protein, is harvested for grain sales and on-farm consumption and the stalks are used for the dairy activity.

In the second stage, the main activity of farms is dairy production. Dairy cows are still fed with natural pastures and forages but there is also an important increase in the use of homemade and purchased concentrates. The use of concentrate permits farms to increase milk productivity and the protein content of milk. A more regular higher milk supply increases farm profits. However, processors complain when milk fat content is high due to the excessive use of concentrate. Many large farmers in Nicaragua are in the second stage, using principally grain of sorghum to produce homemade concentrate or purchasing concentrate to feed their dairy cattle.

In the third stage, farmers use silage which allows them to increase productivity without increasing the milk fat content. The production of silage requires complex

---

[18] This percentage comes from the margin between transportation cost 50 $/ton and farm price $265 $/ton (Table 5).

technical expertise. It also entails more capital than previous stages. Farmers' productivity increases because silage has high protein content and digestibility. Maize silage has slightly better nutritional value than sorghum silage. However, sorghum saves cost by being cut twice or more. Moreover some cultivars specialized for dairy such as Forrajero, can be cut four times. These new cultivars also have similar digestibility and nutritional value with maize. In El Salvador silage use is predominant and milk productivity almost three times that of Nicaragua (Villacis, 2012). El Salvador has largely passed through the first two stages to achieve their current development level in dairy production.

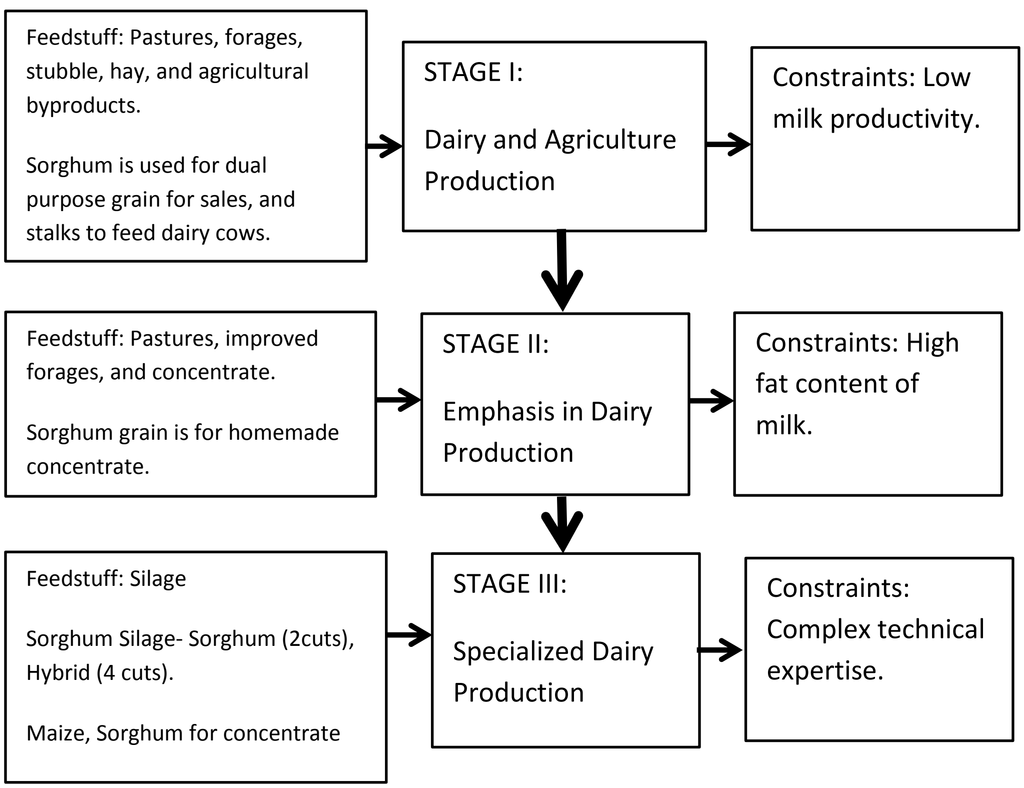

Figure 5. Stages of Dairy Production in Nicaragua.

CHAPTER 4. FARM LEVEL COST SAVING

In this chapter we will determine the cost reduction of milk with and without the new insensitive sorghum technology. We also estimate the cost reduction of grain. First we will discuss productivity differences of milk and grain by farm size as the forage and grain are multi-products. Later we will allocate the production costs of sorghum between dairy and grain production. Finally, we will determine the feed cost savings of milk and of the associated grain production.

4.1 Productivity Difference by Farm Size

There is a yield increase of 0.3 ton per cow from small to large farms (Table 6). This is a minimal increase of only 17%. Large producers have not been able to substantially increase productivity. This contrast significantly with El Salvador experience where large farmers production per cow is almost three times that of small farmers (Villacis, 2012). In Nicaragua milk production continuous to be an extensive activity depending upon pastures and homemade concentrates. With higher milk prices[19] and much less land for expansion El Salvador has shifted to intensive dairy production.

Table 6. Dairy Productivity of Farms with Sorghum Technology

Concept	Farm Size		
	Small	Medium	Large
Herd Size (cows in production)	4	17	36
Milk Production (tons/cow/year)	1.7	2	2
Milk Production (tons/farm/year)	7	33	70

Source: Author's calculations from survey data 2011

[19] The farm price per ton of milk in el Salvador was $423 compared to $288 in Nicaragua (FAO, 2009)

Table 7 displays the dairy production and herd size of a dairy farm without sorghum technology. We observe that yield per cow is almost identical for small, medium, and large dairy farms.

Table 7. Dairy Productivity of Farms without Sorghum Technology

Concept	Farm Size		
	Small	Medium	Large
Herd Size	4	18	39
Milk Production (tons/cow/year)	1.9	1.8	2.1
Milk Production (tons/farm/year)	8	32	81

Source: Author's calculations from survey data 2011

Tables 6 and 7 demonstrate that there are not substantial differences in milk production between farms with and without insensitive sorghum. In fact, we observe that dairy farms with the sorghum technology produce less milk than farms without insensitive sorghum. Farms without sorghum utilize other crops, such as maize, that are more palatable to the cows and have higher content of protein than sorghum. Hence dairy farms without sorghum can obtain higher milk productivity than dairy farms with sorghum.

Farms with insensitive sorghum yield both grain and forage. Small farms' average yield is 1.19 tons/ha hectare and 2 tons of green matter (Table 8). Large farms yield 0.7 tons/ha and 7 tons of forage. Large farms have lower grain yields than small farms because they harvest less grain focusing more on green forage with a few observations of silage. However, large farms yields of green matter are 3.5 times higher than those of small farms.

Small farms allocate 92% of their grain to non-dairy purposes.[20] Large farms allocate 80% of their grain for dairy feeding purposes and only 20% for non-dairy. We observe that small farms plant sorghum focusing on grain production and large farms concentrate to produce forage with some grain to feed their dairy cows.

[20] Non-dairy purpose uses of grain include on-farm consumption and grain sales. On-farm consumption is the grain fed to other farm animals (not cows) and for humans.

Table 8. Grain Productivity of Farms with Insensitive Sorghum

Farm Size	Grain for Dairy		Grain for Non-dairy		Grain Yields	Green Matter Yields
	Tons/Ha	Percentage	Tons/ Ha	Percentage	Tons/Ha	(Tons/Ha)
Small	0.09	8%	1.10	92%	1.19	2
Medium	0.15	11%	1.18	89%	1.34	5
Large	0.56	80%	0.14	20%	0.70	7

Source: Author's calculations from survey data 2011.

4.2 Allocation of Sorghum Production Cost

We allocated the sorghum production cost between dairy and grain production based on the value of sorghum for each activity. The sorghum value for dairy is the forage (green matter) and grain used for dairy purposes (Figure 6). The sorghum value for grain production is the quantity of grain used for non-dairy purposes. We estimated these values multiplying the quantities of grain and forage by their prices. In 2011 the sorghum grain price was particularly higher than previous year. On the dairy part, government keeps milk prices. Hence total benefits of sorghum are higher for medium and large farms that focus their production on grain. Accordingly, the national value of sorghum is higher for grain than for dairy (Figure 7).

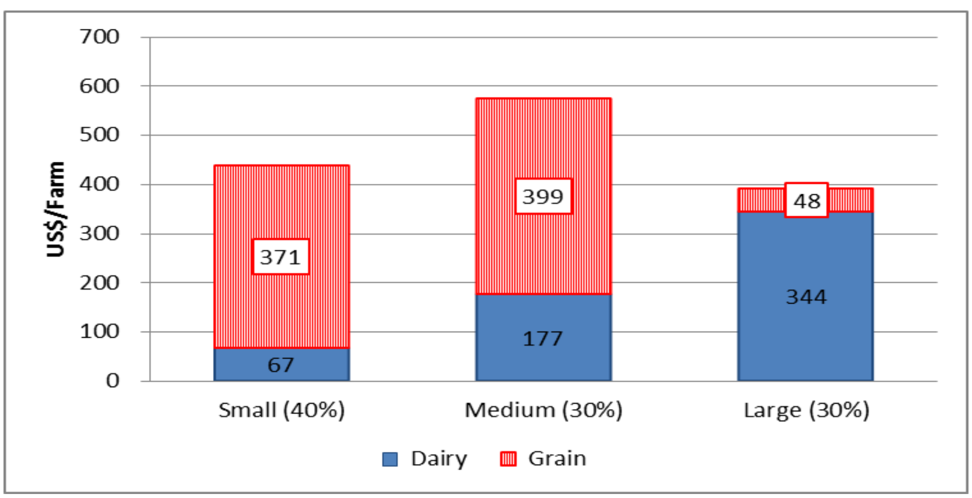

Figure 6. Individual Value of Sorghum per Farm Category

Source: Author's calculations from survey data 2011.

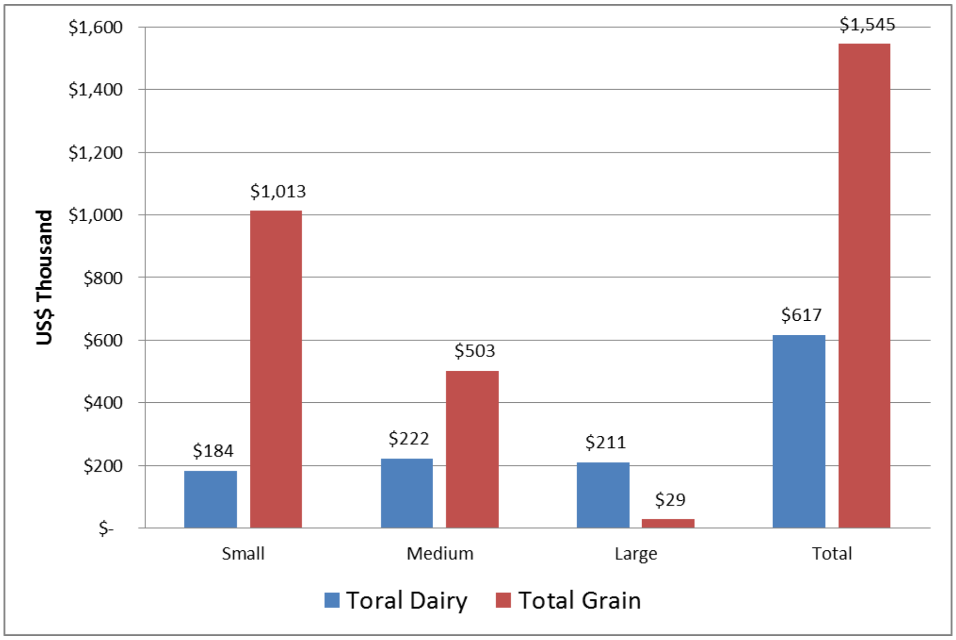

Figure 7. National Value of Sorghum per Farm Activity

Source: Author's calculations from survey data 2011.

Then we calculated the percentage of the value for each activity. As the farm size increases, the value of sorghum for dairy purposes becomes more important than for non-dairy (Table 9). We also observe that the value of grain is important for small and medium farms.

Table 9. Value of Sorghum for Dairy and Grain

Farm Size	Dairy	Grain
Small	15%	85%
Medium	31%	69%
Large	88%	12%

Source: Author's calculations from survey data 2011.

The average cost of production per hectare of sorghum was $175 in 2010.[21] We allocate the sorghum production cost proportionally to the sorghum value between dairy and grain activities. For small dairy farms, we allocate 85% of the sorghum production

[21] This is the cost of planting one hectare of insensitive sorghum. The costs are described in Appendix A.

cost to the grain production and 15% to the dairy activity. Correspondingly, we allocated 88% of the cost to the dairy for large farms (Figure 8).[22]

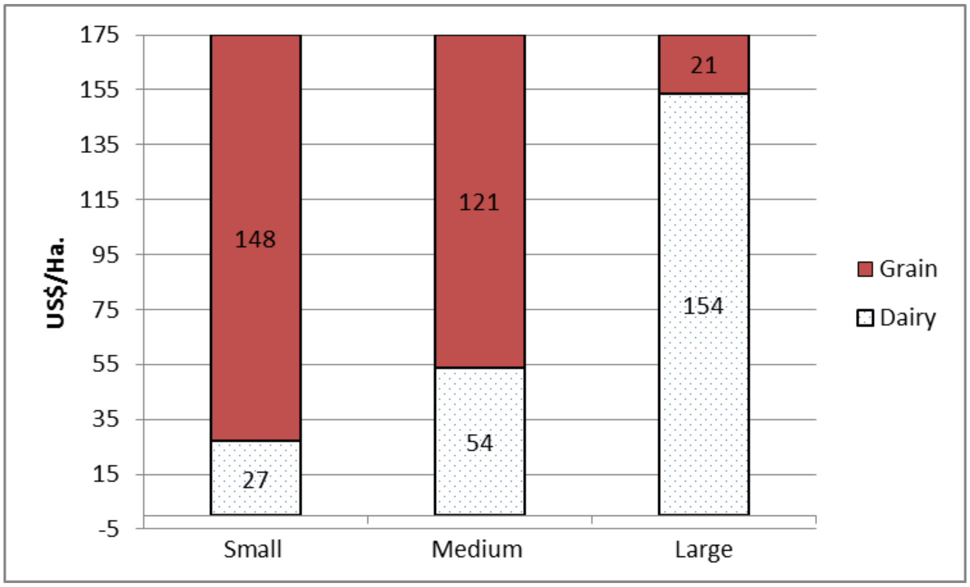

Figure 8. Allocation of Sorghum Production Cost by Farm Size
Source: Author's calculations from survey data 2011.

4.3 Dairy Cost Savings

We estimated the cost savings for dairy production by comparing the feed cost of milk between farms with and without the new insensitive sorghum technology.[23] To calculate the feed cost of milk, we surveyed 120 farms and asked the quantities and prices of feedstuff utilized per cow per day in the rainy season (Invierno[24]) of 2010 and the dry season (Verano[25]) of 2011.

Feed cost per unit of output is the sum of feedstuff costs divided by the dairy production per day. The cost of sorghum feedstuff was partially covered by the grain

---

[22] However, farmers may buy the sorghum feedstuff. If that is the case we should take into account 100% of the sorghum feedstuff cost. We did not collect data on the sorghum feedstuff bought but that appeared to be negligible as no one mentioned it.
[23] The cost of milk only includes feeding cost. There are other important cost including infrastructure, veterinary services, and investment in improved breeds. Within the three size farms comparing sorghum and non-sorghum users these costs were similar.
[24] "Invierno" (winter) is from June to November.
[25] "Verano" (summer) is from December to May of the next year.

activity for farms with sorghum technology. We only counted 15% of the sorghum feedstuff cost for small farms, 31% for medium, and 88% for large. Table 10 displays the feed cost per ton of milk by farm size for dairy producers with the new sorghum technology. Small farms have a cost per ton of milk of 93 U.S. dollars per ton and large farms have a cost of 135 U.S. dollars per ton. Small and medium farms have lower milk cost than large farms because they utilize a higher proportion of agricultural byproducts.

Table 10. Feed Cost per Ton of Milk of Dairy Farms with Sorghum Technology

Farm Size	Cost US$/Ton
Small	93
Medium	97
Large	135

Source: Author's calculations from survey data 2011.

Table 11 shows the cost of milk for dairy farms without sorghum technology. These dairy farms have different feeding preferences, such as other types of crops, forages and commercial concentrates. Small farms' feed cost is $101 per ton of milk, while large farms' cost is $139 per ton of milk.[26] Again small and medium farms have lower feeding cost than large farmers because they use a higher proportion of agricultural byproducts than large farms.

Table 11. Feed Cost per Ton of Milk for Dairy Farms without Sorghum Technology

Farm Size	Cost US$/Ton
Small	101
Medium	98
Large	139

Source: Author's calculations from survey data 2011.

[26] The cost of maize feedstuff is partially covered by the grain production for those farms that planted maize instead of sorghum. We took into account this effect on our feed cost calculations for farms with maize.

Table 12 presents the feed cost reduction per ton of milk for the three farm categories. The cost reduction of milk is the difference between farms with and without the new sorghum technology and it is between 1 and 7 dollars per ton of milk. The cost reduction per bottle of milk is small, between 0.1 to 0.7 ¢. Even though, consumers may not perceive such small savings, we will demonstrate later that the aggregate savings for consumers in the country are substantial.

Table 12. Feed Cost Savings of Milk

Concept	Farm Size		
	Small Farms	Medium Farms	Large Farms
Milk Cost with the technology (US$ /Ton)	93	97	135
Milk Cost without the technology (US$ /Ton)	101	98	139
Milk Reduction Cost (US$ /Ton)	7	1	4
Cost Reduction per bottle (US$ cents/bottle)	0.7	0.1	0.4

Source: Author's calculations from survey data 2011.

There is a feed cost reduction of $7 per ton of milk for small farms. There is also a cost reduction for medium and large farms of 1 and 4 dollars per ton. We will use these parameters to calculate the aggregate benefits of dairy technology in Chapter 6.

4.4 Grain Production Cost Savings

We calculate the savings in the grain market comparing the sorghum and the maize grain cost. White maize is preferred for food in Nicaragua with sorghum as a reserve crop in the hillside when the maize harvest fails.

We estimated the sorghum grain cost per ton using the sorghum production cost per hectare and the quantity of grain used for non-dairy purposes per hectare. Small farms use 1.1 tons of the grain yields per hectare for non-dairy purposes and large farms use only 0.14 tons/ha. We previously calculated the cost allocated to grain production by farm size. Small farms allocate $148 of the sorghum production cost per hectare, medium allocated $121, and large farms allocated $21. Dividing the per hectare costs for grain production by the grain yields (quantity of grain used in grain sales or on-farm use

excluding dairy) gives the average cost per ton of grain (Table 13). Medium farms have the lowest cost per ton at $102. The highest cost is for large farms with 151 $/ton.

Table 13. Sorghum Grain Cost

Farm Size	Grain Non-dairy use (tons/ha)	Cost allocation for grain production ($/ha)	Cost $/ton
Small	1.10	148	135
Medium	1.18	121	102
Large	0.14	21	151

Source: Author's calculations from survey data 2011.

The alternative crop to sorghum is maize. Both sorghum and maize produce forage and grain (for dairy and non-dairy use). The estimated production cost of maize in Nicaragua is $314 per hectare (IICA, 2010, p. 3). The average grain yield per hectare of maize is between 1.1 and 1.4 tons (MIFIC, 2007, p. 8).[27] We estimated the quantity of maize grain used for non-dairy purposes with the same proportions for dairy and grain as with sorghum. We also allocated the cost of maize between dairy and grain activity as with sorghum cost allocation. Again dividing the per hectare costs for grain production by the grain yields (quantity of grain used in grain sales and on-farm use excluding dairy) gives the average cost per ton of grain for maize (Table 14).

Table 14. Maize Grain Cost

Farm Size	Grain Non-dairy use (tons/ha)	Cost allocation for grain production ($/ha)	Cost $/ton
Small	1.2	266	226
Medium	1.3	218	172
Large	0.2	38	253

Source: Author's calculations from IICA 2010 and MIFIC, 2007.

To compare sorghum and maize grain cost per ton we included the price difference. The price of a ton of maize in 2010 was $29 higher than the price of sorghum.

[27] On the Pacific plains agricultural yields are higher than in other zones of Nicaragua. Hence we will make our calculation with a maize grain yield of 1.4 tons/ha.

Table 15 shows the cost savings after subtracting the price difference from the cost savings. In the grain market, savings range between 40 to 73 dollars per ton. Large farms have higher cost savings than small and medium farms. These parameters will be the basis to calculate the agregatte benefits in the grain market in the chapter 6.

Table 15. Grain Cost Savings

Farm Size	Cost Saving (with price difference) $/ton
Small	62
Medium	40
Large	73

Source: Author's calculation from survey data 2011, IICA 2010 and MIFIC 2007.

4.5 Conclusions

The main impact of the new technology is on dairy production and concentrated on the large farms (Figure 9). Small and medium farms do not experience these large benefits on dairy. The large farms are clearly focused on the dairy activities while the opposite is true of the small farmers. For small and medium farms, the annual benefits of dairy are smaller than the benefits of grain. So the dairy activities from the new technologies do not have an equitable distribution among farm sizes for the individual farmer. In Chapter 6 we will estimate the aggregate benefits by farm size sector and also bring in the consumer benefits.

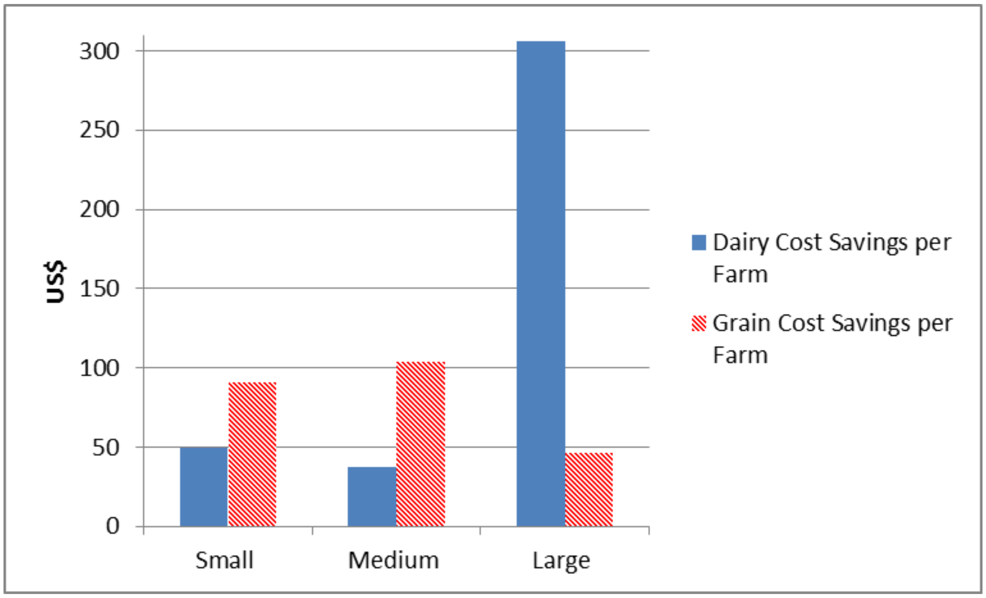

Figure 9. Annual Dairy and Grain Cost Savings per Farm

Source: Author's calculations from survey data 2011 and IICA 2010.

CHAPTER 5. METHODOLOGY

In the previous chapter we estimated the cost saving effects of the new sorghum for dairy and grain production at the farm level. In this chapter we will develop a model to estimates the national gains to consumers, producers, and processors in the dairy market and the associated grain production. We will also estimate the rate of return to the agricultural research for both markets in Nicaragua and the combined effects.

First we will describe the model theory and show it in a graph. Then we will derive the algebraic formulas for a parallel shift of supply. After that, we discuss the model assumptions. Finally, we list the parameters needed to calculate the benefits of research for the new insensitive cultivars for the dairy and associated grain production.

5.1. Economic Surplus Method

Figure 10 shows a comparative-static, partial-equilibrium model of supply and demand for a commodity market. This model exemplifies the economic surplus effects of technological changes and measures the total surplus, and the share of the benefits between producers and consumers surpluses. Consumer surplus combines the willingness to pay and what consumers actually pay for a good or service. Consumer benefits are measured as the area under the demand curve and over the price. Individual producer surplus is the difference between what producers are willing to accept (marginal cost) and what they actually receive for a good. Total producer surplus in a market is the sum of the individual producer surpluses of all the sellers of a good. Total producer surplus is the area under the market equilibrium price and over the supply curve (Harry & Richard, 2003).

Figure 10 illustrates the effect of a new technology on a commodity market. The initial supply curve, demand curve, quantity, and price are S_0, D, P_0, and Q_0 respectively. After the introduction of the new technology, the new supply curve, quantity and price are S_1, Q_1, and P_1. The change in consumer surplus is the area P_0-a-b-P_1, the change in producer surplus is the area P_1-b-c-I_0, and the area I_0-a-b-I_1 is the gross annual research benefit.

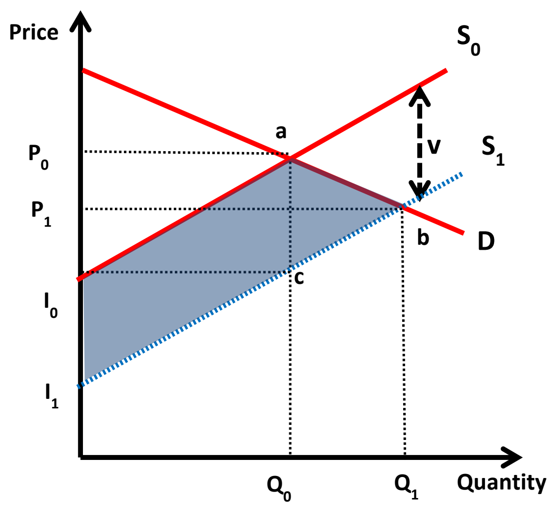

Figure 10. Economic Surplus Components from a Supply Shift.
Source: Alston, 1995, p. 28.

5.2. Model Representation

Freebairns, Davis, and Edwards (1982) developed a model to determine the impact of a new technology and the distribution of research gains in a multistage production system. Figure 11 displays the multistage model and the distribution of the gains after the introduction of a new technology. "Df" is the demand curve at the farm level, "Dr" represents the demand for the final consumer, "Sf_0" and "Sf_1" represent the supply curves, "v" is the cost reduction per unit of output, and "M" is the processor margin. The initial equilibrium quantity and price are "Pf_0", "Pr_0", and "Q_0". After the introduction of the new technology, the new equilibrium quantity and prices are Pf_1, Pr_1, and Q_1.

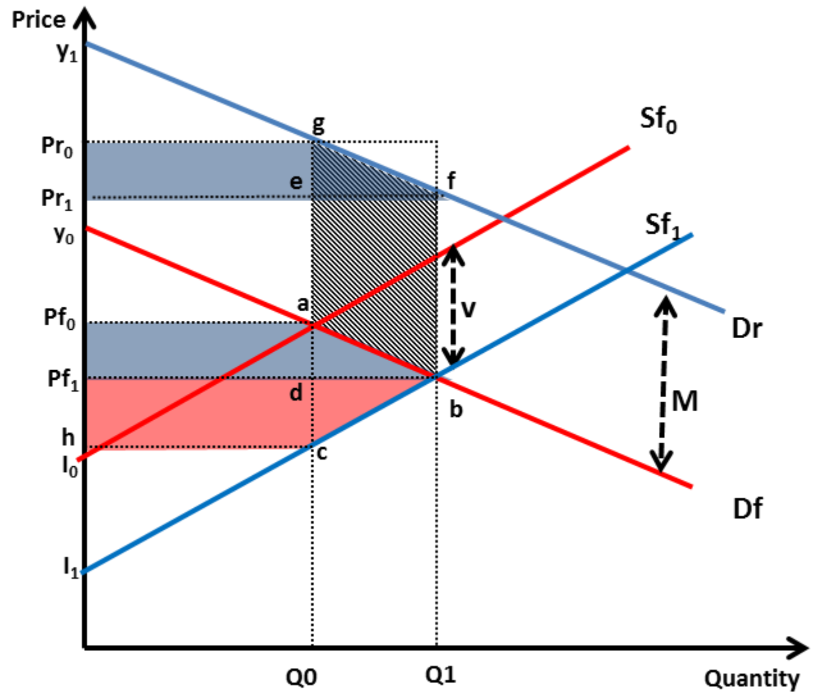

Figure 11. Multistage Production System with a Technological Change

Source: Adopted from Freebairns, Davis, & Edwards, 1982.

Here there is a parallel shift of the supply curve and a constant margin between demand curves. We divided the benefits into change in consumer surplus (Pf_0-a-b-Pf_1)[28], change in producer surplus (Pf_1-b-c-d) and change in processors surplus (g-f-b-a)[29].

5.3. Model Geometric Expression

From figure 11, the geometric equation of the change in consumer surplus is:

$$\Delta CS = (P_{r0} - P_{r1}) * Q_1 - \frac{1}{2} * (P_{r0} - P_{r1}) * (Q_1 - Q_0) \qquad \text{(a)}$$

Accordingly, the change of producer surplus is:

$$\Delta PS = \left(P_{f1} - h\right) * Q_1 - \frac{1}{2} * \left(P_{f1} - h\right) * (Q_1 - Q_0) \qquad \text{(b)}$$

The change in processor surplus is:

[28] This area is also equal to Pr_0-g-f-Pr_1.

[29] We assume constant margin "M" between the processor "Dr" and farm demand "Df". The initial processor surplus is equal to the area P_{r0} -g-a-P_{f0} this is equal to "$M*Q_0$". After the introduction of the new technology the new retailer surplus is equal to P_{r1}-e-d-P_{f1} plus e-f-b-d or "$M*Q_0+M*(Q_1-Q_0)$". The change in processor surplus is equal to e-f-b-d "$M*(Q_1-Q_0)$". Area g-f-b-a is equal to "$M*(Q_1-Q_0)$". Hence, area e-f-b-d is equal to area g-f-b-a.

$\Delta RS = Q_1 * \left(P_{r1} - P_{f1}\right) - Q_0 * (P_{r0} - P_{f0})$ (c)

Consequently, the change in total surplus is:

$\Delta TS = \Delta CS + \Delta PS + \Delta RS$ (d)

5.4. Derivation of the Algebraic Expression of the Model

Assuming that the margin of processor is constant, the difference $P_{r0} - P_{r1}$ is equal to $P_{f0} - P_{f1}$. Then, the equation for consumer surplus is:

$\Delta CS = \left(P_{f0} - P_{f1}\right) * Q_1 - \frac{1}{2} * \left(P_{f0} - P_{f1}\right) * (Q_1 - Q_0)$ (a)

The supply and demand functions are denoted as:

$Q_S = B + \beta * (P + v)$

$Q_D = A - \alpha * P$

Where "β" and "α" are the slopes of supply and demand function, and "v" is the average cost reduction resulting from the adoption of the new technology.

Beginning from the equilibrium:

$Q_S = Q_D$

$B + \beta * P + \beta * v = A - \alpha + P$

$\beta * P + \alpha * P = A - B - \beta * v$

We get the equilibrium price:

$$P = \frac{A - B - \beta * v}{\alpha + \beta}$$

P_0 is the initial equilibrium price in the absence of the new technology. At this point, there is no cost saving effect, so "v" is equal to cero. Hence,

$$P_0 = \frac{A - B}{\alpha + \beta}$$

P_1 is the price after the adoption of the new technology.

$$P_1 = \frac{A - B - \beta * v}{\alpha + \beta}$$

Subtracting P_1 from P_0 we get equation:

$P_0 - P_1 = \frac{\beta * v}{\alpha + \beta}$ (e)

In order to find the Q_1-Q_0, we substitute P_0 in Q_D.

$Q_0 = A - \alpha * P_0$

$$Q_0 = A - \alpha * \left(\frac{\alpha - B}{\alpha + \beta}\right)$$

And P_1 in Q_D

$$Q_1 = A - \alpha * \left(\frac{A - B - \beta * v}{\alpha + \beta}\right)$$

We subtract Q_1 from Q_0 and we get

$$Q_1 - Q_0 = A - \frac{\alpha * A - \alpha * B - \alpha * \beta * v}{\alpha + \beta} - A + \frac{\alpha * A - \alpha * B}{\alpha + \beta}$$

$$Q_1 - Q_0 = \frac{\alpha * A - \alpha * B}{\alpha + \beta} - \frac{\alpha * A - \alpha * B - \alpha * \beta * v}{\alpha + \beta}$$

$$Q_1 - Q_0 = \frac{\alpha * \beta * v}{\alpha + \beta} \qquad \text{(f)}$$

We substitute (e) and (f) in the geometric expression of the consumer surplus (a) and we obtain:

$$\Delta CS = \left(\frac{\beta * v}{\alpha + \beta}\right) * Q_1 - \frac{1}{2} * \left(\frac{\beta * v}{\alpha + \beta}\right) * \left(\frac{\alpha * \beta * v}{\alpha + \beta}\right)$$

$$\Delta CS = \frac{Q_1 * \beta * v}{\alpha + \beta} - \frac{1}{2} * \frac{\alpha * \beta^2 * v^2}{(\alpha + \beta)^2} \qquad (g)$$

Subsequently, the change in producer surplus (2) is:

$$\Delta PS = (P_{f1} - d) * Q_1 - \frac{1}{2} * (P_{f1} - d) * (Q_1 - Q_0)$$

Figure 11 shows that

$$(P_{f1} - h) = (P_{f0} - h) - (P_{f0} - P_{f1})$$

The cost saving effect "v" is equal to:

$$(P_{f0} - h) = v$$

$$(P_{f1} - h) = v - (P_{f0} - P_{f1})$$

$$(P_{f1} - h) = v - \frac{\beta * v}{\alpha + \beta}$$

$$(P_{f1} - h) = \frac{\beta v + \alpha v - \beta v}{\alpha + \beta}$$

$$(P_{f1} - h) = \frac{\alpha v}{\alpha + \beta} \qquad \text{(h)}$$

Substituting (h) and (f) in producer surplus (b) we get:

$$\Delta PS = \frac{\alpha v}{\alpha + \beta} * Q_1 - \frac{1}{2} * \frac{\alpha v}{\alpha + \beta} * \frac{\alpha * \beta * v}{\alpha + \beta}$$

$$\Delta PS = \frac{\alpha Q_1 v}{\alpha + \beta} - \frac{\alpha^2 \beta v^2}{2(\alpha + \beta)^2} \qquad (i)$$

The equation for the change in processor surplus[30] is:

$\Delta RS = Q_1 * (P_{r1} - P_{f1}) - Q_0 * (P_{r0} - P_{f0})$

The difference between processor and farm price is equal to the margin "M".

$\Delta RS = Q_1 * (M) - Q_0 * (M)$

$\Delta RS = M * (Q_1 - Q_0)$

We substitute the "M" and (f) in (c).

$$\Delta RS = M * \frac{\alpha * \beta * v}{\alpha + \beta} \qquad \text{(j)}$$

Finally, the total change in surplus is equal to:

$\Delta TS = \Delta CS + \Delta PS + \Delta RS$

$$\Delta TS = Q_1 \ \beta - \frac{\alpha\beta \ v^2}{2(\alpha + \beta)} + M * \frac{\alpha * \beta * v}{\alpha + \beta} \qquad (k)$$

Summarizing, the algebraic equations to calculate the consumer, producers, processor, and total surplus are:

$$\Delta CS = \frac{Q_1 * \beta * v}{\alpha + \beta} - \frac{1}{2} * \frac{\alpha * \beta^2 * v^2}{(\alpha + \beta)^2} \qquad (g)$$

$$\Delta PS = \frac{\alpha Q_1 v}{\alpha + \beta} - \frac{\alpha^2 \beta \ v^2}{2(\alpha + \beta)^2} \qquad (i)$$

$$\Delta RS = M * \frac{\alpha * \beta * v}{\alpha + \beta} \qquad \text{(j)}$$

$$\Delta TS = Q_1 \ \beta - \frac{\alpha\beta \ v^2}{2(\alpha + \beta)} + M * \frac{\alpha * \beta * v}{\alpha + \beta} \qquad (k)$$

Where the parameter "v" is the average cost reduction per unit of output[31] after the new technology adoption, M is margin between producer and retailer price, α is the slope of the demand function, β is the slope of the supply curve, and Q_1 is observed quantity after the introduction of the technology. The values of α and β can be calculated from the formulas of demand and supply elasticities for the dairy market.

$$\alpha = \eta * \frac{Q_1}{P_1}; \ \beta = \gamma * \frac{Q_1}{P_1}$$

[30] The processor surplus will be adjusted for the percentage of milk processed to calculate the processors surplus.

[31] For this study the unit of milk output is 1 ton that is equal to 1,000 liters.

5.5. Adjustment of the Cost Reduction for the Adoption Level

Figure 12 shows the total area of new insensitive dairy sorghum and total white (insensitive) sorghum in Nicaragua. This figure shows a steady increase of the sorghum areas of new insensitive sorghum.

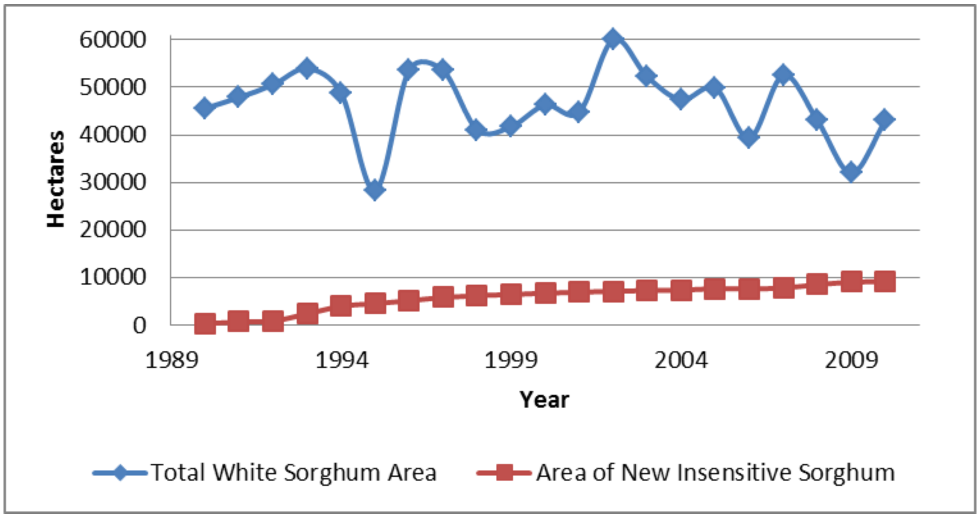

Figure 12. Areas of New Insensitive Sorghum and Total White Sorghum in Nicaragua. Source: Estimates from Gutierrez, Obando, and Vargas 2011 and BCN 2010.

The average cost reduction "v" from the new technology for the different farm sizes was calculated in Ch.4 (Table 12) but in the aggregate this also depends upon the level of adoption in each of the farm size categories. To estimate the adopted areas in new technologies we used the estimates of INTA sorghum breeders. According to their estimates, small dairy farms plant 40% of the area in the new insensitive sorghum cultivars, medium dairy farms 30%, and large dairy farms 30% (Obando, 2011). Based on these percentages and the average area planted per farm size, we estimated the number of farms in each farm size category adopting (Appendix B). To estimate the milk production under the new technology, we multiply the average farm milk production of adopters times the number of farms in each farm size category (also see Appendix C).

The cost reduction in the aggregate also depends on the adoption level of the technology. We use equation (l) to calculate the farm size category national level cost reduction.

$$v_{ai} = \frac{v_i * q_i}{q} \qquad (l)$$

Where "v_i" is the cost savings per ton of milk per farm size shown in table 12 in Ch. 4 for adopters, q_i is the total milk produced by farm size category with the new technology, and q is the national milk production. This is the average saving in each farm size category adjusted for the extent of adoption. This "v" then will enable us to calculate the economic surplus benefits to each size category in Ch. 6. Then the cost reduction in the country depends upon both the cost savings of each farm size category and the importance of each category in the total milk produced with the new technology (the percentages of milk produced in each sector were given in Chapter 3, Table 4).

$$V\ weighted = Va_{(small\ farms)}*29\% + Va_{(medium\ farms)}*44\% + Va_{(large\ farms)}*27\%$$

We also adjusted the grain cost saving to the national adoption level. Based on the area planted under the new technology and grain yield (used for non-dairy purposes) per farm we estimated the quantity of grain produced by farm size (see appendix G).
We also used equation (l) to calculate the saving cost adjusted for the national level. Where "v_i" is the saving cost per ton of grain per farm size (shown in Table 15), q_i is the grain produced by farm size category with the new technology, and q is the combined total grain production of maize and sorghum. Appendices H, I and J show the adjusted grain saving cost by farm size. After we got the adjusted saving cost per farm size, we also estimated the weighted adjusted saving cost based on the percentage of farms on each farm category.

5.6 Model Assumptions

To calculate the benefits of the insensitive sorghums for dairy and grain production we make the following assumptions.

- The supply and demand elasticity values are constant throughout the study period.
- The margin between producer and processor prices is constant in the dairy market.

Milk is considered a basic component of the diet with few substitutes. Hence, we use an inelastic demand elasticity of -0.2 for dairy.[32] For supply elasticity, Nicaragua has abundant pasture areas and dual purpose herds[33], so we use a supply elasticity of 0.6. In the grain market, sorghum has more substitutes. We use a demand elasticity of -0.4. Other studies, even in middle income developing countries, show that supply elasticity for sorghum ranged between 0.4 and 0.5 (FAPRI, 2012). Since insensitive sorghum is concentrated in the better agricultural regions of Nicaragua, we consider the middle income country elasticity of supply estimate to be better than the lower income country elasticity estimate. Hence we use a supply elasticity of 0.5.

The processor margin is the difference between farm and processed milk price. According to the discussion of margins on page 22 in chapter 3, pasteurized milk has a processor margin of 98% and accounts for 21% of the total milk production. There was a transportation margin of 19% for the remaining 79% of the dairy production. A weighted margin of processed and non-processed milk is then employed for this study.

5.7. Data and Parameters

Questionnaires were administered on 120 dairy farms in nine departments of the Pacific plains in Nicaragua. These questionnaires were designed to collect data of herd size, feed cost, milk yields per cow, farming technology, grain yields, sorghum area and grain use. Research and extension cost data were collected from INTA records.

Data were collected from FAO statistics for the quantity of milk production, sorghum and white maize grain production, farm milk prices, farm grain prices for sorghum and maize, sorghum areas and yields in Nicaragua. INTA and The National Association of Sorghum Producers (ANPROSOR) provided data of insensitive sorghum areas for dairy production, and the distribution of those areas between small, medium, and large farmers. Additional data were collected from National Institute of Information and Development (INIDE) and the Central Bank of Nicaragua for milk retail prices,

[32] There are no previous studies for price elasticity of demand or supply for milk and sorghum in Nicaragua. But there are studies for many other Latin American countries (FAPRI, 2012)

[33] With dual purpose herds, it is relatively easy to shift herd from meat to milk production.

quantity of milk processed, and consumer price index. Supplementary data about milk intermediaries, collection centers, milk processors, and retailers were collected from the Agricultural and Forestry Agency of Nicaragua (MAGFOR).

5.8 Conclusions

We developed the algebraic equations to calculate the consumers, processors, and producers' benefits for the parallel supply shifts. We established the parameters and data that we will use to calculate the benefits. We will use the multistage model to calculate the benefits of consumers, processors, and producers in the dairy market. We will use a simple surplus model to calculate consumer and producers benefits in the grain market. In the following chapter, we will incorporate the parameters and data collected in the model to estimate the benefits and returns to agricultural research of the new insensitive sorghum cultivars in the dairy-grain market.

CHAPTER 6. RESULTS

6.1 Introduction

In this chapter we calculated the gains for consumers, producers, and processors, and the rate of return to new sorghum technology in dairy production. We also calculated the consumer and producer surplus in the associated grain production. Then we combine these benefits to estimate an overall rate of return.

6.2 Benefits in the Dairy Market

Figure 13 shows the feeding cost of milk in U.S. dollars per ton with and without the technology. Small farms have the lowest feeding cost (inframarginal firms) and a cost reduction of 7 dollars per ton. Medium farms have a cost reduction of 1 dollar per ton. Large farms have the highest feeding cost (marginal firms) and a cost reduction of 4 dollars per ton. Supply shift is divided in two sections: from small to medium and from medium to large. In the first section, the absolute cost reduction for small farms is greater than the cost reduction of medium farms. This is a convergent supply shift. The second section the cost reduction is pivotal. Trend lines showed in figure 13 indicate that supply shift approximates to parallel. Hence we use the parallel shift assumption to estimate the benefits of the insensitive sorghums in the dairy market.

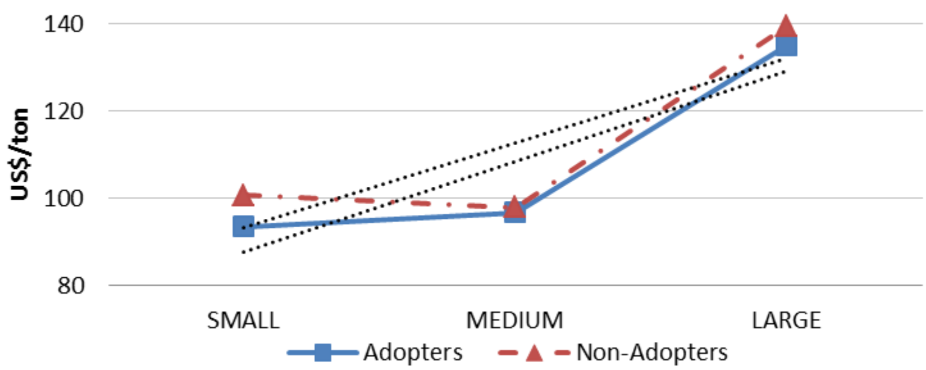

Figure 13. Feed Cost for Milk by Efficiency of Producers.
Source: Author's calculations from the survey data 2011.

To calculate the benefits per year, we incorporated the data of milk prices, milk production, adoption rates, and adjusted average feed cost reduction in the algebraic equations of consumer gains (g), processor gains (j), producer gains (i), and total gains (k) in the dairy market. We made these calculations with a price elasticity of demand of -0.2 and a price elasticity of supply of 0.6 for milk (Appendix K).

Figure 14 displays the annual stream of benefits to consumers, processors, and producers in the dairy market. Consumers are the primary beneficiaries of the new insensitive sorghum technology in the dairy market. The annual benefit to consumers in 2010 was 90 thousand dollars. Large farms are the main beneficiaries among producers. We added the benefits to calculate the total private benefits.

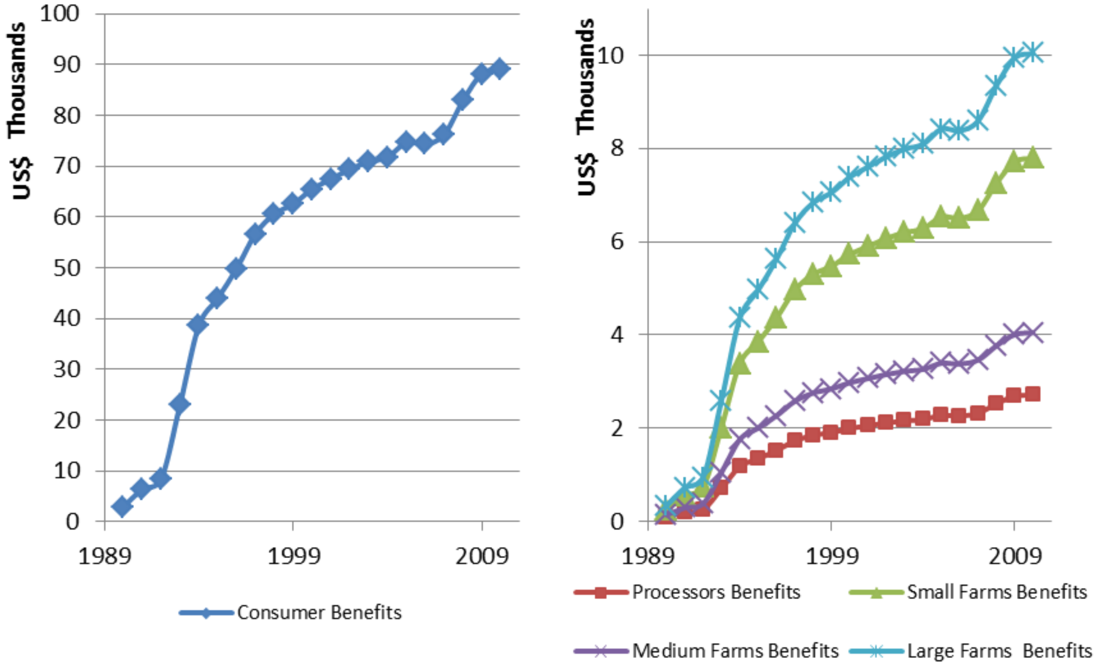

Figure 14. Gross Benefits Sorghum Technology in the Dairy Market.
Source: Model results and author's calculation from survey data 2011.

In order to calculate the net social benefits, we subtracted the research and extension costs from the total net private benefits. Table 16 shows the average research cost of a dual purpose insensitive sorghum cultivar. We incorporated the costs that INTA invested to adapt the sorghum cultivars to the local conditions. The cultivar adaption period normally takes five years. Additionally, there is a three year period of field evaluation in different experiment stations around the country. The total research and development period per cultivar takes eight years and costs 157 thousand dollars. The research costs include infrastructure, salary of scientists and extension agents, cost of land for trials, materials, and cost of registration for the new cultivars.

Table 16. Research Cost for a New Sorghum Cultivar

Concept	US$ (Thousands)
Planting and seed Selection	90
Regional Evaluations	3
Seed Certification Cost	4
Transportation	11
Land	9
Scientist, Specialist, Assistants	28
Infrastructure	6
Laboratories	1
Promotion	6
Total	157

Source: Obando, 2011.

We divide the research cost of insensitive sorghum between dairy and grain production. We allocated the research cost based on the value of sorghum for each product (Chapter 4, Table 9). We weighted these values based on the INTA's breeder estimation of percentage of insensitive sorghum area cultivated by each farm size (40% small farms, 30% medium farms, and 30% large farms). Hence, we allocated 42% of research cost to dairy and 58% to grain production.

The stream of annual research costs began in 1985, with the development of Pinolero-1, and continued until 2010. Figure 15 presents the cumulative research cost of the new insensitive sorghum cultivars for dairy production. By 2010 the total research and extension costs for dairy were 370 thousand U.S. dollars.

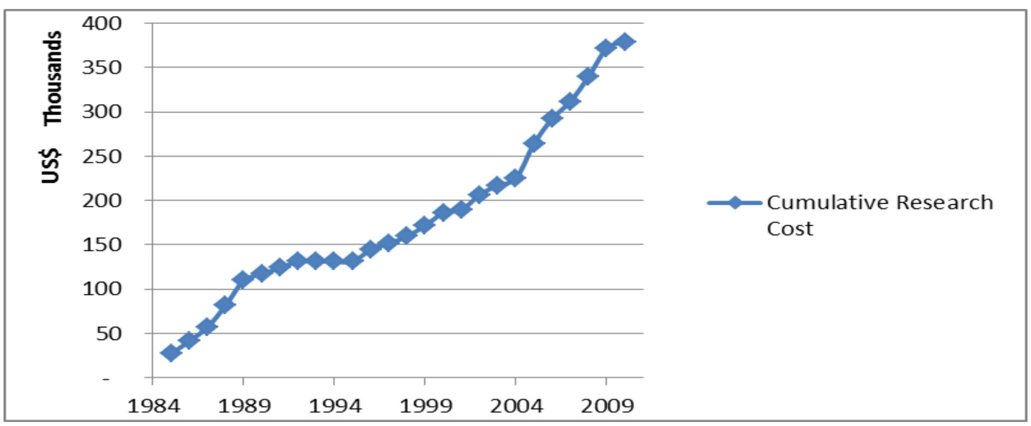

Figure 15. Cumulative Research Cost for Dairy.

Source: Author's calculation from Obando 2011.

We calculated the stream of the net social benefits in the dairy market by subtracting the research cost of dairy from the dairy net private benefits. Figure 16 shows the stream of annual net benefits in the dairy market corresponding to the adoption of the new insensitive sorghum technology. In the early years, between 1985 and 1990, there were only annual flows of research costs and no social benefits. Pinolero-1 was released in 1986 but during the civil war there was little diffusion of this cultivar. Rapid adoption of Pinlero-1 occurred after the civil war finished in 1990. At this time, the corresponding positive flow of social benefit began.

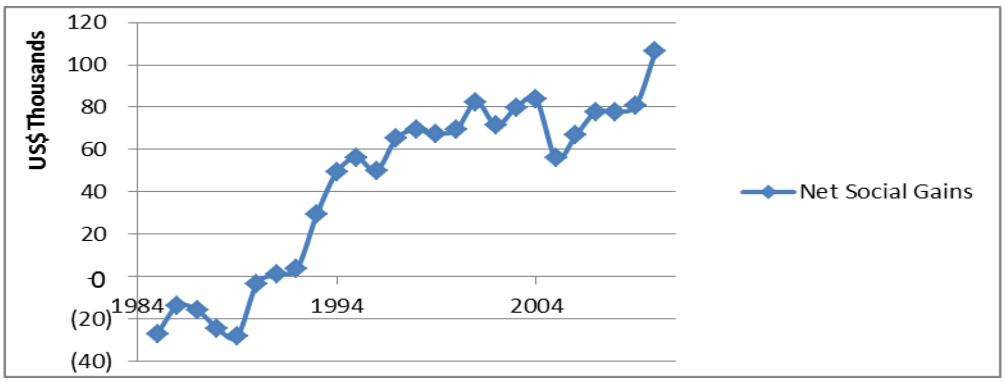

Figure 16. Net Social Benefits from the Introduction of Sorghum for Milk Production. Source: Model results and author's calculation from survey data 2011.

The net social benefits were estimated at $1.13 million. We then calculated the internal rate of return for the insensitive sorghums in the Nicaraguan dairy market. Table 17 summarizes the social benefits, cost, and rate of return of the insensitive sorghum research for the dairy market. The model results indicate that the internal rate of return of the project in the dairy market is 20%. The insensitive sorghum research project is cost-effective in the dairy market because the IRR is larger than the opportunity cost of public funds.[34] The main beneficiaries in the dairy market are the consumers. Among producers, large dairy producers obtain larger benefits than small or medium farms. Medium producers have the lowest benefit among producers because of their small cost savings.

[34] The social discount rate or rate of return on public funds was estimated for Nicaragua at 12% (Ministerio de Hacienda y Credito Publico, 2010).

Table 17. Benefits and Returns in the Dairy Market

Concept	US$(Thousands)
Consumer	1183
Processors	36
Producers	291
Small Farms	104
Medium Farms	54
Large Farms	133
Private Benefits	1510
Research Costs	379
Net Social Benefits	1131
IRR	20%

Note. η=-0.2, γ=0.6; Parallel Shift of Supply.

Source: Model results and author's calculation from survey data 2011.

6.3 Benefits in the Grain Market

Figure 17 shows the production costs in U.S. dollars per ton for sorghum and for maize by farm size. Besides feed in dairy sorghum and maize are used as food and as feed for other animals. We calculated the cost reduction per ton of grain (Chapter 4, Table 15) medium farms have the lowest grain cost of 131.48 $/ton (inframarginal firms) and a cost reduction of 40 dollars per ton. Large farms have the highest grain cost of 179$/ton (marginal firms) with a cost reduction of 73 dollars per ton. Here we also approximated this shift with a parallel shift of supply to estimate the benefits of the insensitive sorghums in the grain market. [35]

[35] There is some divergence between small and medium producers.

Figure 17. Grain Cost by Producers' Efficiency.

Source: Author's calculations from survey data 2011 and IICA 2010.

To calculate the benefits per year, we combined the data of grain prices, grain production, adoption rates, and adjusted average feed cost reduction and the algebraic equations of consumer gains (g), producer gains (i), and total gains (k) in the grain market. We used a price elasticity of demand of -0.4 and a price elasticity of supply of 0.5 (see Appendix M).

Figure 18 and 19 display the annual stream of consumers and producers' benefits in the grain market. Consumers' surplus is divided into consumers' surplus due to producers' grain sales and consumers' surplus to producers due to on-farm consumption.[36] Producer surplus was calculated from the production cost savings per ton of grain.

[36] This surplus is due to the on farm use of grain for human, poultry, and swine consumption.

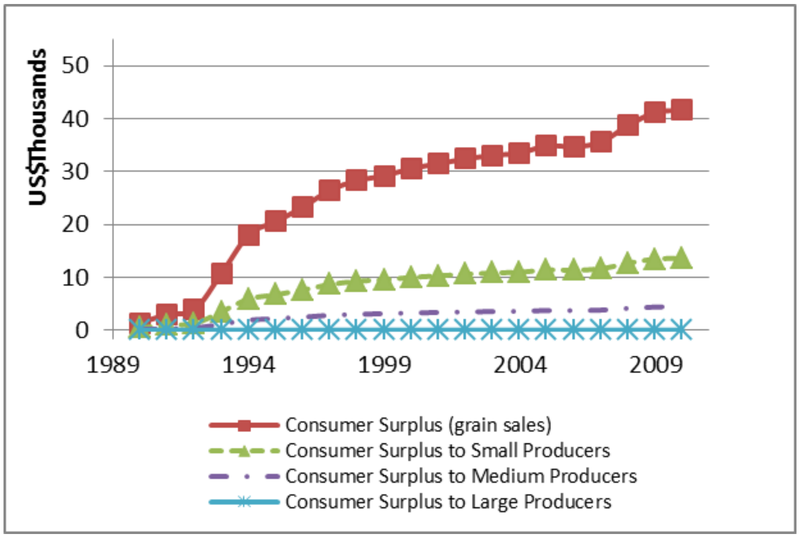

Figure 18. Consumers' Gross Benefits in the Grain Market.

Source: Model results and author's calculation from survey data 2011.

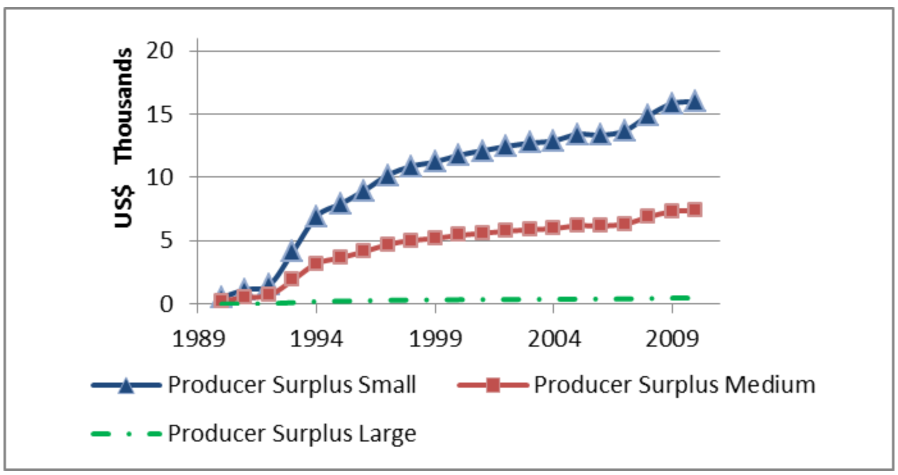

Figure 19. Producers' Surplus in the Grain Market.

Source: Model results and author's calculation from survey data 2011.

To calculate the total producers benefit, we added the consumers' surplus for producers to the producers' surplus from the grain cost reduction. Figure 20 displays the total producers' benefits by farm size and grain consumer surplus. The group that benefits most from the insensitive sorghum technology in the grain market is consumers. Benefits to large producers are small because large producers use most of their grain in dairy rather than in sales or on-farm use in contrast with small and medium producers.

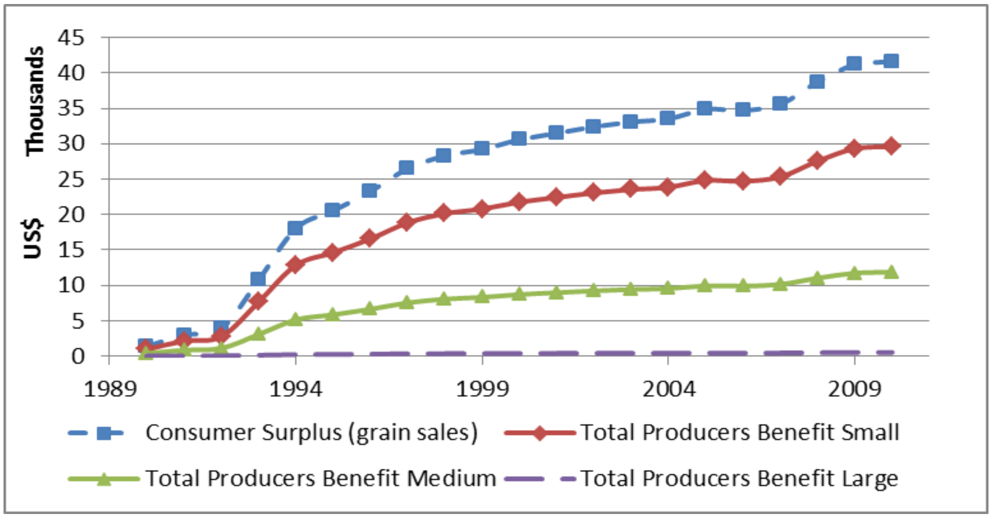

Figure 20. Total Benefits to Producers and Consumers in the Grain Market.

Source: Model results and author's calculation from survey data 2011.

To calculate the net social benefits in the grain market, we subtracted the research and extension costs from the net private benefits. We allocated 58% of the research cost to grain production.[37] Figure 21 displays the cumulative research cost of the new insensitive sorghum cultivars for grain production. By 2010 the total research and extension cost for grain was 520 thousand U.S. dollars.

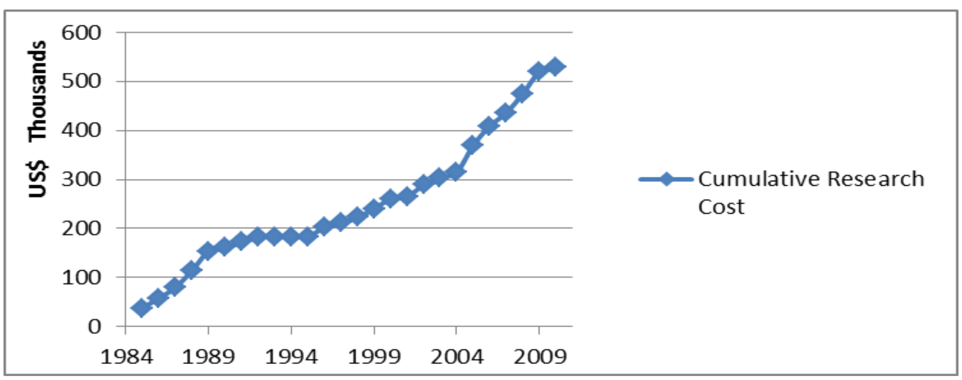

Figure 21. Cumulative Research Cost for Grain.

Source: Author's calculation from Obando 2011.

[37] We allocated the research cost for the development and extension of the insensitive sorghum technologies based on the weighted value of sorghum for dairy and grain production.

We calculated the stream of the net social benefits in the grain market by subtracting from the grain net private benefits the public research and extension costs for grain (Figure 22). In the first five years there were only annual flows of research costs and negative net social benefits. After 1990 adoption increases and net social benefits turn positive.

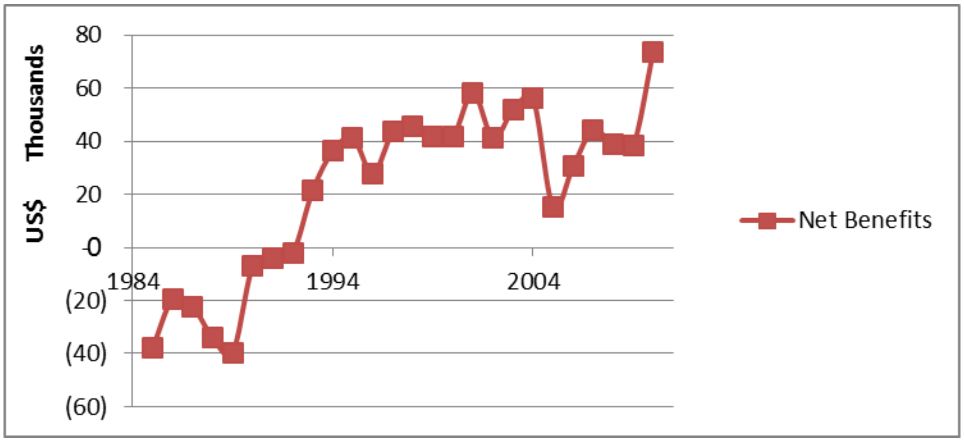

Figure 22. Net Social Benefits for the Insensitive Sorghums in the Grain Market.
Source: Model results and author's calculation from survey data 2011.

Using the annual stream of net social benefits, we estimated the internal rate of return for the insensitive sorghums in the Nicaraguan grain market. Table 18 and 19 summarizes the social benefits, cost, and rate return of the insensitive sorghum research in the grain market. The model results indicate that the internal rate of return for this project in the grain market is 12%. This return is equal to the opportunity cost of public funds. The main beneficiaries in the grain market are the consumers followed by small producers. The benefits to large producers are small since their grain production allocated for non-dairy purposes is minimal.

Table 18. Consumer and Producer Surplus in the Grain Market

Concept		US$ (Thousands)
Consumer Surplus		552
Consumer Surplus to Producers	Small	181
	Medium	59
	Large	1
Producer Surplus	Small	212
	Medium	98
	Large	6

Note. η=-0.4,γ=0.5; Parallel Shift of Supply.

Source: Model results and author's calculation from survey data 2011.

Table 19. Return and Benefits to Producers and Consumers in the Grain Market.

Concept		US$ (Thousands)
Consumer Surplus		552
Total Benefits to Producers	Small	393
	Medium	157
	Large	7
Private Benefits		1110
Research Cost		530
Net Social Benefits		734
IRR		12%

Note. η=-0.4, γ=0.5; Parallel Shift of Supply.

Source: Model results and author's calculation from survey data 2011.

6.4 Aggregate Sorghum Benefits

We added the consumers, processors, and producers' surplus from the dairy and grain market to calculate the total benefit of the insensitive sorghum cultivars in Nicaragua (Table 20). We found that consumers are the main beneficiaries of the sorghum research project in Nicaragua. Among producers, small farms are the group that gets most benefits from the insensitive sorghum project.

Table 20. Benefits and Return from Grain and Dairy

Concept	US$ (Thousands)
Consumers' Surplus	1,735
Processors' Surplus	36
Small Producers' Surplus	497
Medium Producers' Surplus	211
Large Producers' Surplus	140
Total Private Benefits	2,619
Total Research Cost	909
Net Social Benefit	1,711
IRR	16%

Source: Model results and author's calculation from survey data 2011.

Figure 23 shows that consumers obtain almost 70% of their surplus from the dairy market. Benefits of small farms come mainly from the grain market. Small farms use sorghum mainly for grain sales and on-farm use. Medium farms also obtain significant gains especially from the grain market with over 65% of their benefits from the grain market. In contrast, most of the gains for large farms come from dairy and grain benefits are less than 10% of these producers. As farms size increases, the share of gains that comes from dairy production increases. This is because large farms need of feedstuff for dairy increases with herd size. Large farms have to specialize to produce feedstuff for dairy. While small and medium farms can still base their dairy cows diet on agricultural byproducts and use sorghum grain for non-dairy purposes.

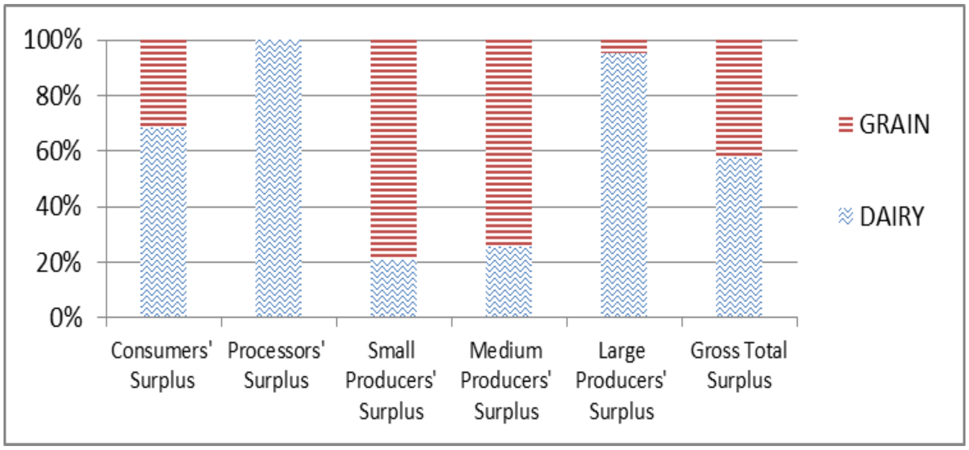

Figure 23. Share of the Benefits between Grain and Dairy Market.

Source: Model results and author's calculation from survey data 2011.

6.5 Conclusions

Results from the dairy market and its associated grain production indicate that the main beneficiaries of the new insensitive sorghum cultivars are consumers. On the producers' side, small farmers get more than three times the benefit of large farms. Their benefits are primarily from the grain sales and on-farm use. In contrast, large farms obtain most of their gains from the dairy market. These large farms use more sorghum homemade concentrate and a few large farms use silage. But large farmers were not able to increase very much their productivity in comparison with small farmers. All farm sizes face similar low prices compared with El Salvador and all have more available le land for extensive production.

Results have shown the rate of return to the sorghum project overall in Nicaragua is 16%. If we compare this rate to the social opportunity cost, the sorghum project was positive. However this rate of return is not substantially higher than the opportunity cost of public funds in Nicaragua.

CHAPTER 7. SENSITIVITY ANALYSIS

Previously, we calculated the benefits assuming a price elasticity of demand for milk of -0.2 and a supply elasticity of 0.6. In this chapter we calculate the distribution of the benefits under alternative scenarios changing the supply and demand elasticity assumptions.

We considered milk as a necessity good that has few substitutes. Consumers do not decrease substantially their milk consumption with increases in the milk price. Rather they reallocate their expenditures on other foods. Hence, in the results chapter we made our calculations with a demand elasticity of -0.2.

An alternative assumption is that with an increase in milk price families would consume less milk to maintain their consumption of rice and beans. Then we would have underestimated the value of the price elasticity of the demand. To consider this case a demand elasticity of -0.4 will be used to generate an alternative scenario with less inelastic milk prices.

One of the principal and high-priced inputs for dairy production is land. However, Nicaraguan land pressures are not as constrained as in other countries in the region. Farmers can increase dairy output by increasing the grazing area which is relatively cheaper than in El Salvador or Costa Rica. Also they have already herds for meat and milk so that they can shift between them increasing their proportion of milk cows. So we used a fairly high supply elasticity of 0.6. We also consider the case with an even higher supply elasticity of 0.8.

Table 21 presents the distribution of the gains under four scenarios. The first scenario shown in row 1 represents the initial assumptions and is presented in the results

chapter. This scenario serves as a baseline for this discussion of comparison between scenarios.

The second scenario shows a more elastic supply of 0.8. We changed this parameter because we recognized that it is possible that dairy production is more responsive to price motivations with their land and herd size availabilities. Under scenario 2 with the higher supply elasticity, consumers' benefits in the dairy market increase since with even greater output response milk price reduction is larger than that of the initial scenario. Hence, milk consumption is larger than in the initial situation. Assuming that the processors' margin is constant, dairy processors will be better off because the quantity produced and consumed in the dairy market increases. Hence, processors sell more milk and their surplus increase. On the other hand, change in dairy producers' surplus is negative. The price reduction has a larger impact on their aggregate revenues than the additional quantity of milk produced.

The third scenario shows an increase in absolute value of the demand elasticity from 0.2 to 0.4 because it is possible milk consumption is more sensitive to change in prices as people adjust their diet to higher milk prices. In this case there is more substitution of other foods when the milk price increases. Under this scenario, consumers' benefits decrease and producers' surplus increase. A more elastic demand results in increasing benefits for producers (Alston, 1995). Clearly the degree of substitution for milk when prices increase is an empirical question. Our judgment is that at present income levels and knowledge about nutrition most Nicaraguan consumers attempt to maintain milk consumption for children even with higher milk prices.

The forth scenario combines a more elastic demand and supply. Under this scenario the change in producers' surplus is positive and consumer surplus is reduced. For producers, this situation is not as good as the third scenario of an increase (absolute) of the milk price elasticity with no change in the supply elasticity.

Table 21. Distribution of Economic Surplus with Different Demand and Supply Elasticities

Scenario	η	γ	Dairy Market		
			Consumer Gains	Processor Gains	Producer Gains
1	-0.2	0.6	1,183	36	291
2	-0.2	0.8	1,244	38	229
3	-0.4	0.6	988	77	625
4	-0.4	0.8	1,077	66	397

Note: Benefits expressed in Thousands of 2010 US$.

Source: Model results and author's calculation from survey data 2011.

Figure 24 shows that as supply elasticity become more elastic (keeping demand elasticity constant at -0.2), consumers and processors share of the benefit increase and producer gains decrease. On the other hand, as elasticity of demand becomes more elastic (keeping supply elasticity constant at 0.6), consumers' share of the benefits decrease and processors and producers' gains increase. Based on our field experience, we consider that scenario 1 is a good approximation to calculate the returns to agricultural research for the Nicaraguan dairy production.

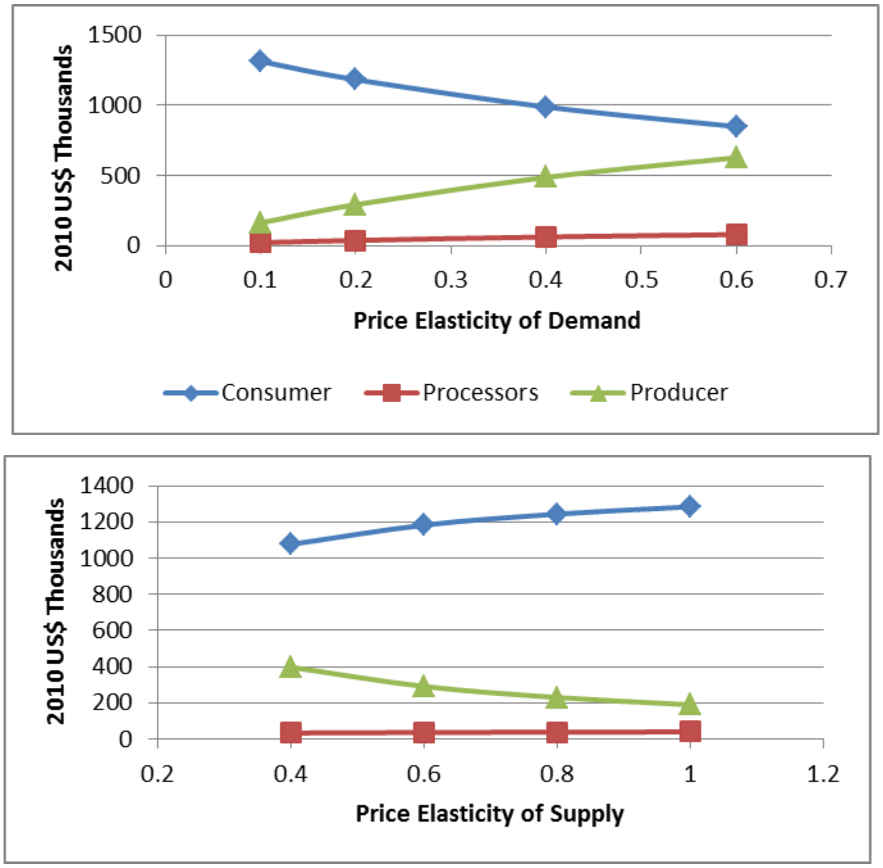

Figure 24. Sensitivity Analysis Varying Supply and Demand Elasticities.

Source: Model results and author's calculation from survey data 2011.

CHAPTER 8. CONCLUSIONS

Historic results have shown positive but low returns to insensitive sorghum research in Nicaragua. The return was 20% in the dairy market and 13% in the grain market. The aggregate rate of return for the total sorghum project was 16%. This rate of return is slightly higher than the social opportunity cost of Nicaraguan public funds.

In the dairy market the main beneficiaries were consumers. Among producers large dairy farms obtain higher benefits than small and medium farms.

The main beneficiaries in the grain market were also consumers. Among producers there was a concentration of benefits for small farmers due to their focus on grain. There were important benefits of consumers to producers (this is the grain that farmers do not sell but use as input in non-dairy activities mainly poultry and swine feed and some human food). The on-farm use of grain was an important source of surplus for producers especially for small farms.

In general the main beneficiaries of sorghum research were consumers. Small cost savings per bottle are not easily perceived by consumers. This thesis documents that when we aggregate these small savings consumers obtain very large benefits from the dairy research.

With economic growth, demand for higher quality products such as milk increases very rapidly, hence agricultural research projects are very important for consumers. Without investment in sorghum research, consumers would have to pay higher milk prices and reduce their dairy consumption.

There were also important benefits for producers, especially for small and medium farms in the grain market. But with the increasing dominance of the dairy sector expected over time benefit distribution within agriculture is expected to become regressive.

Nicaraguan milk production is in the incipient stages of dairy development. Milk production is just starting to shift from an extensive system to an improved intensive production. Many of the small and medium farms are still in the initial stage of dairy development. However, large farms have begun to move towards a more developed stage. These farms have begun specialization in dairy production and to use more sophisticated technology including concentrates and the initiation of silage use. As Nicaraguan incomes increase, consumption of high quality products including milk will also increase rapidly. With greater demand milk prices will increase and there will be greater incentives for producers especially large producers to rapidly shift to more intensive systems of milk production. Public policies such as price control to maintain milk price low would restrain price increases to consumers but also discourage farmers, especially large farmers, from a more rapid shift to more intensive techniques. El Salvador's development of the dairy sector has shown that it is easier for the large farmers than small and medium farmers to make these shifts to a series of higher technical requirements for increased dairy production. El Salvador has almost three times the productivity level of milk production that Nicaragua has (Villacis, 2012).

In making this public decision on milk price controls it is important to remember that consumers, especially low income consumers, are expected to be the major beneficiaries of the expansion of the dairy system and they were the major beneficiaries in El Salvador. Hence, slowing the process of this shift with lower milk prices will slow down the long term effect of substantial benefits to consumers, especially low income consumers, from the modernization of the dairy sector. There will be regressive income distribution effects within agriculture as the large farmers will capture most of the benefits but in the overall society including consumers the total effects are expected to be progressive.

As dairy production becomes more specialized, small farms are expected to shift to more labor intensive activities for which demand is increasing rapidly especially in urban areas. So we expect shifts to fruit and horticulture production. We do not expect small farms to shift from dairy to beef production because they do not have large grazing lands or large herd sizes and there are expected to be returns to scale in beef production.

The future benefits from the research on improved insensitive sorghums are expected to be higher than the estimated returns here. The new sorghum cultivars released in recent years have even better features than their predecessors for dairy production. These new cultivars, especially INTA Forrajero, are expected to be adopted rapidly because of their potential to reduce dairy feeding cost. Four cuts are possible with this cultivar. Also new BMR sorghum cultivars will be released soon. One has been released in the spring of 2012. These BMR sorghums have similar protein content and palatability as maize and will be able to reduce dairy cost and increase productivity per cow with not only multiple cuts but also higher quality.

We expect that the benefits will be concentrated around urban areas with good transportation systems. An analysis of the spatial distribution of benefits would be interesting for future studies. A spatial economics study would contribute to focus the technical support and extension programs on certain areas where the dairy production is more efficient.

Further work on the demand and supply elasticities would be helpful to understand how these change in the process of development and to make them more relevant to specific regions.

LIST OF REFERENCES

LIST OF REFERENCES

Akino, M., & Hayami, Y. (1975). Efficiency and Equity in Public Research: Rice breeding in Japan's Economic Develoment. *American Journal of Agricultural Economics*.

Akino, M., & Hayami, Y. (1975). Efficiency and Equity in Public Research: Rice breeding in Japan's Economic Develoment. *American Journal of Agricultural Economics*.

Alston, J. M. (1995). *Principles and Practice for Agricultural Research Evaluation and Priority Setting.* Ithaca: Cornell University Press .

Banco Central de Nicaragua. (2009). *Estadisticas Macroeconomicas Anuales 1960-2009. Tazas de crecimiento.* Managua.

Banco Central de Nicaragua. (2010). *Nicaragua en cifras.* Retrieved 3 13, 2012, from http://www.bcn.gob.ni/estadisticas/economicas_anuales/nicaragua_en_cifras/2010/Nicaragua_en_cifras2010.pdf

Banco Central de Nicaragua. (2010). *Produccion de granos Basicos.* Managua. Retrieved from http://www.bcn.gob.ni/estadisticas/economicas_anuales/50_anios/BD/Capitulo_I-Sector_real/I-15.pdf

Banco Central de Nicaragua. (2012). Produccion pecuaria: Acopio de leche. Managua, Nicaragua. Retrieved from http://www.bcn.gob.ni/estadisticas/trimestrales_y_mensuales/siec/demoFrameset.html

BCN. (2010). *Produccion de Granos Basicos.* Managua: Banco Central de Nicaragua. Retrieved from

http://www.bcn.gob.ni/estadisticas/economicas_anuales/50_anios/BD/Capitulo_I-Sector_real/I-15.pdf

BCN. (2012). *Banco Central de Nicaragua. Indice de Precios al Consumidor (IPC).* Managua. Retrieved from http://www.bcn.gob.ni/estadisticas/trimestrales_y_mensuales/siec/datos/4.IPCM.1.htm

Camara Nicaraguense del Sector Lacteo CANISLAC. (2007, Diciembre). Contribucion a la Formulacion de Propuestas de Politicas Publicas y Privadas para el Benefcio del Sector Lacteo.

Cordero, C. (2011). *Analisis de los Resultados de los Indicadores Tecnicos de los Beneficiarios del Proyecto Occidente Ganadero.* Leon: Consultorias y Servicios Pecuarios CONSERPE. Retrieved from http://www.cuentadelmilenio.org.ni

Delgado, C. L. (2003). Rising consumption of Meat and Milk in Developing Countries Has Created a New Food Revolution. *The Journal of Nutrition*, 1-2. Retrieved 03 13, 2012, from http://jn.nutrition.org/content/133/11/3907S.full.pdf

Estebez, R., & Clara, R. (2010). *Ensayo de Variedades de Sorgos Forrajeros y Graniferos "bmr" El Salvador.* Centro Nacional de Tecnologia Agropecuaria y Forestal. Retrieved from http://intsormil.org/smscientificpresents/2011%20PCCMCA%20Mtg/VARIEDADES%20DE%20SORGO%20BMR%202010.pdf

FAO. (2009). *Food and Agriculture Organization* . Retrieved from FAO Statistics Producer Price (US $/Ton): http://faostat.fao.org/site/703/DesktopDefault.aspx?PageID=703#ancor

FAO. (2009). *Food and Agriculture Organization of the United Nations*. Retrieved from Producer Milk Prices: http://faostat.fao.org/site/703

FAO Statistics. (2010). *Food and Agriculture Organization of The United Nations*. Retrieved 03 13, 2012, from Production Livestock Primary Milk: http://faostat.fao.org/site/569

FAO Statistics. (2010, June 02). *Food and Agriculture Organizations of The United Nations*. Retrieved 03 13, 2012, from Food Supply. Livestock and Fish Primary Equivalent: http://faostat.fao.org/site/610/default.aspx#ancor

FAO Statistics. (2010). *Sorghum Gross Production Value (current million US$).* Food and Agricultural Organization of The United Nations. Retrieved from http://faostat.fao.org/site/613/DesktopDefault.aspx?PageID=613#ancor

FAPRI. (2012). *Elasticity Database.* Ames: Food and Agrcitulral Policy Research Institute. Retrieved from http://www.fapri.iastate.edu/tools/elasticity.aspx

Freebairns, J., Davis, J. S., & Edwards, G. W. (1982). *Distribtuion of Research Gains in Multistage Production Systems.* American Agricultural Economics Association.

Gutierrez, N. (2004). *Caracterizacion del Fotoperiodismo y Agromorfologia de 14 Variedades de Sogo Millon en Tres Epocas de Siembra en CNIA.* Managua: Universidad Nacional Agraria. Farcultad de Agronomia Departamento de Produccion Vegetal .

Harry, C., & Richard, B. (2003). *Benefit-Cost Analysis. Finnacial and Economic Appraisal using Spreadsheets.* Cambridge University Press.

IICA. (2005). Estudio de La Cadena de Comercializacion de La Leche. Managua. Retrieved March 13th, 2012, from http://books.google.com/books

IICA. (2010). *Mapeo de Las Cadenas Agroalimentarios de Maiz Blanco y Frijol en Centroamerica.* Managua: Instituto Interamericano de Cooperacion para la Agricultura.

INETER. (2005). *Instituto Nicaraguense de Estudios Territoriales*. Retrieved from Metereologia en Nicaragua : http://webserver2.ineter.gob.ni/Direcciones/meteorologia/clima%20nic/caracteristicasdelclima.html

INIDE. (2010). *Instituto Nacional de Informacion de Desarrollo*. Retrieved from Reporte Anual de Precio y Costo de 53 productos de la canasta Basica 1995-2009.: http://www.inide.gob.ni/

INTA . (2010). *Tortillero Precoz.* Managua, Nicaragua: Instituto Nicaraguense de Tecnologia Agropecuaria INTA.

INTA. (2004). *INTA-CNIA. Nueva Variedad de Sorgo Blanco para Grano.* Managua : Instituto National de Tecnologia Agropecuaria.

INTA. (2009). *Guia Tecnologica. Cultivo del Sorgo* . Managua, Nicaragua : Instituto Nicaraguense de Tecnologia Agropecuaria.

INTA. (2010). *Perfil INTA-Sorgo Mejor.* Managua: Instituto Nicaraguense de Tecnologia Agropecuaria.

INTA. (2010). *Plegable INTA RCV* . Managua : Instituto Nicaraguense de Tecnologia Agropecuaria.

INTA. (2010). *Plegable INTA-Forrajero* . Managua: Instituto Nicaraguense de Tecnologia Agropecuaria.

INTA. (2010). *Sorgo de Grano Blanco Variedad Pinolero-1.* Managua : Instituto de Tecnologia Agricola INTA.

INTA. (2011). *Mejoramos la alimentacion del Ganado en epoca seca.* Managua: Instituto Nacional de Tecnologia Agropecuaria. .

Lindner, R. K., & Jarret, F. G. (1978). Supply Shifts and the Size of Research Benefits. *American Journal of Agricultural Economics, Vol. 60, No. 1*, 49-58. Retrieved from http://www.jstor.org/stable/1240160

Longman. (1972). Monocotyledons. In P. J. W, *Tropical crops* (pp. 259-286).

MAGFOR. (2008, 10). *Ministerio Agropecuario y Forestal de Nicaragua.* Retrieved 03 13, 2012, from Subprograma Inversion de Desarrollo Integral para la Produccion de Leche en Polvo de Alcance Regional : http://www.magfor.gob.ni/prorural/programasnacionales/perfilessub/plantalactea.pdf

MAGFOR. (2008, 10). *Subprograma Inversion de Desarrollo Integral para la Produccion de Leche en Polvo de Alcance Regional.* Retrieved 03 13, 2012, from Ministerio de Agricultura y Forestal de Nicaragua: http://www.magfor.gob.ni/prorural/programasnacionales/perfilessub/plantalactea.pdf

MAGFOR. (2010). *Ministerio Agropecuario y Forestal. Agriculutura: Area, Produccion, y Rendimiento.* Managua.

Masters, W. A. (1996). *The Economic Impact of Agricultural Research: A Practical Guide.* West Lafayette: Department of Agricultural Economics, Purdue University.

MIFIC. (2007). *Maiz Blanco Nicaragua.* Managua: Ministerio de Fomento Industria y Comercio. Retrieved from http://www.mific.gob.ni

MIFIC. (2007, February). *Minisiterio de Fomento, Industria y Comercio: Ficha Productos Lacteos Queso, Leche, Mantequilla y Crema.* Retrieved March 3th, 2012, from Direccion de Politica Comercial Externa: http://www.mific.gob.ni

Ministerio de Hacienda y Credito Publico. (2010). *Tasa Social de Descuento Nicaragua.* Managua : Gobierno de Reconciliacion y Unidad Nacional .

Norton, G. W., Ganoza, V. G., & Pomareda, C. (1987). Potential Benefits of Agricultural Research and Extension in Peru. *Agricultural and Applied Economics Association*, 247-257.

Obando, R. (2010, 09 29). Sorgo Forrajero. *El Pueblo Presidente*. Retrieved from http://www.elpueblopresidente.com/AGROFORESTAL/6499.html

Obando, R. (2011, August 14). Distribution of Insensitive Sorghum . (G. Garcia, Interviewer)

Obando, R. (2011). *Research and Extension Cost.* Managua: INTA.

Pineda, L. (1997). La produccion de sorgo granifero en Nicaragua y su manejo bajo condiciones de secano. Instructivo Tecnico. Managua, Nicaragua: INTA-CNIA.

Pinstrup-Andersen, P., Londono, N. R., & Hoover, E. (1976). The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research and Policy. *American Journal of Agricultural Economics*.

PROCIG. (2012). *Mapa de Nicaragua.* Central American Geographic Information Project. Retrieved from http://www.procig.org/ing/procig-nicaragua.htm

Restrepo, J., Murgeitio, E., & Preston, T. (1991). Milk Production Systems in Tropical Latin America. Dual Purpose Cattle Production Systems. 189. Retrieved March 13th, 2012, from http://www.fao.org/ag/aga/agap/frg/AHPP86/Restrepo.pdf

The World Bank. (2012). *Data*. Retrieved 03 13, 2012, from How we Classify Countries : http://data.worldbank.org/about/country-classifications

Valdivia, R. (2010). *Manejo Agronomico de Sorgo Millon.* Managua: Catholic Relief Services. Retrieved from http://a4n.com.sv/uploaded/mod_documentos/MANEJO%20AGRONOMICO%20DE%20SORGO-MILLON.pdf

Villacis, A. (2012). Returns to the Introduction of New Sorghum Cultivars into The Dairy Industry of El Salvador. *Department of Agricultural Economics, Purdue University*.

World Bank Data. (2011). *World Development Indicators and Global Development Finance*. Retrieved 03 13, 2012, from GDP per capita, PPP (current internationl $): http://databank.worldbank.org

APPENDICES

Appendix A. Cost of Insensitive Sorghum per Hectare

Concept	Cost US$/Ha
Land Preparation	47
Seed Cost	7
Planting	18
Fertilizer	50
Pest Control	10
Harvesting	29
Grain Drying	14
Total Cost	175

Source: Author's calculations from survey data 2011.

Note: The fertilizer and pest control cost includes the application cost of these inputs per hectare.

Appendix B. Area and Number of Farms Under the New Technology

Year	Total Areas of the New Insensitive Sorghums	Area Planted under New Tech by small farmers (Ha)	Area Planted under New Tech by medium farmers (Ha)	Area Planted under New Tech by Large farmers (Ha)	Number of small Farms using New Tech	Number of Medium Farms using New Tech	Number of Large Farms using New Tech
1989	0	0	0	0	0	0	0
1990	300	120	90	90	90	41	20
1991	650	260	195	195	195	90	44
1992	850	340	255	255	255	118	57
1993	2350	940	705	705	704	325	158
1994	3950	1580	1185	1185	1184	546	266
1995	4500	1800	1350	1350	1349	622	303
1996	5100	2040	1530	1530	1529	705	343
1997	5800	2320	1740	1740	1739	802	390
1998	6200	2480	1860	1860	1859	857	417
1999	6400	2560	1920	1920	1919	885	430
2000	6700	2680	2010	2010	2008	926	450
2001	6900	2760	2070	2070	2068	954	464
2002	7100	2840	2130	2130	2128	982	477
2003	7250	2900	2175	2175	2173	1002	487
2004	7345	2938	2204	2204	2202	1015	494
2005	7640	3056	2292	2292	2290	1056	514
2006	7607	3043	2282	2282	2280	1052	511
2007	7796	3118	2339	2339	2337	1078	524
2008	8485	3394	2546	2546	2544	1173	570
2009	9024	3610	2707	2707	2705	1248	607
2010	9113	3645	2734	2734	2732	1260	613

Source: Authors calculations from the survey data; Gutierrez, Obando, and Vargas, 2011.

Appendix C. New Technology Milk Production and National Milk Production

Year	New Tech Milk Production Small Farms	New Tech Milk Production Medium Farms	New Tech Milk Production Large Farms	Total Milk Produced Under New Tech	Total Milk Produced by small farms	Total Milk Produced by medium farms	Total Milk Produced by large farms	Total National Milk Production
1990	614	1355	1403	3372	46160	68901	42859	157920
1991	1331	2936	3040	7307	48229	71990	44781	165000
1992	1741	3839	3975	9555	49983	74608	46409	171000
1993	4813	10614	10991	26417	53703	80161	49863	183727
1994	8089	17841	18474	44403	54731	81694	50817	187242
1995	9216	20325	21046	50586	54846	81866	50924	187636
1996	10444	23035	23852	57331	57131	85278	53046	195455
1997	11878	26196	27126	65200	61130	91247	56759	209136
1998	12697	28003	28997	69697	63758	95170	59199	218127
1999	13107	28906	29932	71945	146149	218152	135699	500000
2000	13721	30261	31335	75317	163687	244330	151983	560000
2001	14130	31164	32271	77566	164995	246283	153198	564476
2002	14540	32068	33206	79814	159053	237413	147680	544145
2003	14847	32745	33908	81500	167051	249352	155106	571509
2004	15042	33174	34352	82568	171621	256174	159350	587145
2005	15646	34507	35732	85884	179506	267942	166670	614118
2006	15578	34358	35577	85513	194245	289944	180356	664545
2007	15965	35211	36461	87638	202015	301541	187570	691127
2008	17376	38323	39683	95383	210128	313651	195103	718882
2009	18480	40758	42204	101442	218583	326272	202954	747809
2010	18662	41160	42621	102443	220183	328659	204439	753281

Note: Dairy production is in tons.

Source: Made with data collected at Survey 2011, FAO Statistics 2011, Gutierrez, Obando, and Vargas, 2011.

Appendix D. Parameter ν for Small Farmers

Year	Total Area Planted under New Tech (Ha)	Area Planted under New Tech by small farmers (Ha)	Number of small Farms using New Tech	New Tech Milk Production Small Farms (ton)	Total Milk Produced by small farms (ton)	Total National Milk Production (ton)	ν (small Farmers)
1990	300	120	90	614	46160	157920	0.03
1991	650	260	195	1331	48229	165000	0.06
1992	850	340	255	1741	49983	171000	0.07
1993	2350	940	704	4813	53703	183727	0.19
1994	3950	1580	1184	8089	54731	187242	0.31
1995	4500	1800	1349	9216	54846	187636	0.36
1996	5100	2040	1529	10444	57131	195455	0.39
1997	5800	2320	1739	11878	61130	209136	0.41
1998	6200	2480	1859	12697	63758	218127	0.42
1999	6400	2560	1919	13107	146149	500000	0.19
2000	6700	2680	2008	13721	163687	560000	0.18
2001	6900	2760	2068	14130	164995	564476	0.18
2002	7100	2840	2128	14540	159053	544145	0.19
2003	7250	2900	2173	14847	167051	571509	0.19
2004	7345	2938	2202	15042	171621	587145	0.19
2005	7640	3056	2290	15646	179506	614118	0.18
2006	7607	3043	2280	15578	194245	664545	0.17
2007	7796	3118	2337	15965	202015	691127	0.17
2008	8485	3394	2544	17376	210128	718882	0.18
2009	9024	3610	2705	18480	218583	747809	0.18
2010	9113	3645	2732	18662	220183	753281	0.18

Source: Made with data collected at Survey 2011, FAO Statistics 2011, Gutierrez, Obando, and Vargas, 2011

Appendix E. Parameter ν for Medium Farmers

Year	Total Area Planted under New Tech (Ha)	Area Planted under New Tech by medium farmers (Ha)	Number of medium Farms using New Tech	New Tech Milk Production Medium Farms (ton)	Total Milk Produced by medium farms (ton)	Total National Milk Production (ton)	ν (medium Farmers)
1990	300	90	41	1355	68901	157920	0.01
1991	650	195	90	2936	71990	165000	0.02
1992	850	255	118	3839	74608	171000	0.03
1993	2350	705	325	10614	80161	183727	0.07
1994	3950	1185	546	17841	81694	187242	0.11
1995	4500	1350	622	20325	81866	187636	0.12
1996	5100	1530	705	23035	85278	195455	0.13
1997	5800	1740	802	26196	91247	209136	0.14
1998	6200	1860	857	28003	95170	218127	0.15
1999	6400	1920	885	28906	218152	500000	0.07
2000	6700	2010	926	30261	244330	560000	0.06
2001	6900	2070	954	31164	246283	564476	0.06
2002	7100	2130	982	32068	237413	544145	0.07
2003	7250	2175	1002	32745	249352	571509	0.07
2004	7345	2204	1015	33174	256174	587145	0.06
2005	7640	2292	1056	34507	267942	614118	0.06
2006	7607	2282	1052	34358	289944	664545	0.06
2007	7796	2339	1078	35211	301541	691127	0.06
2008	8485	2546	1173	38323	313651	718882	0.06
2009	9024	2707	1248	40758	326272	747809	0.06
2010	9113	2734	1260	41160	328659	753281	0.06

Source: Made with data collected at Survey 2011, FAO Statistics 2011, Gutierrez, Obando, and Vargas, 2011

Appendix F. Parameter ν for Large Farmers

Year	Total Area Planted under New Tech (Ha)	Area Planted under New Tech by large farmers (Ha)	Number of large Farms using New Tech	New Tech Milk Production large Farms (ton)	Total Milk Produced by large farms (ton)	Total National Milk Production (ton)	ν (large Farmers)
1990	300	90	20	1403	42859	157920	0.04
1991	650	195	44	3040	44781	165000	0.08
1992	850	255	57	3975	46409	171000	0.10
1993	2350	705	158	10991	49863	183727	0.26
1994	3950	1185	266	18474	50817	187242	0.43
1995	4500	1350	303	21046	50924	187636	0.49
1996	5100	1530	343	23852	53046	195455	0.54
1997	5800	1740	390	27126	56759	209136	0.57
1998	6200	1860	417	28997	59199	218127	0.59
1999	6400	1920	430	29932	135699	500000	0.26
2000	6700	2010	450	31335	151983	560000	0.25
2001	6900	2070	464	32271	153198	564476	0.25
2002	7100	2130	477	33206	147680	544145	0.27
2003	7250	2175	487	33908	155106	571509	0.26
2004	7345	2204	494	34352	159350	587145	0.26
2005	7640	2292	514	35732	166670	614118	0.26
2006	7607	2282	511	35577	180356	664545	0.24
2007	7796	2339	524	36461	187570	691127	0.23
2008	8485	2546	570	39683	195103	718882	0.24
2009	9024	2707	607	42204	202954	747809	0.25
2010	9113	2734	613	42621	204439	753281	0.25

Source: Made with data collected at Survey 2011, FAO Statistics 2011, Gutierrez, Obando, and Vargas, 2011

Appendix G. Grain Production under New Technology

Year	Total Grain Production	Grain Production by Small Farms (tons)	Grain Production by Medium Farms (tons)	Grain Production by Large Farms (tons)
1989	-	-	-	-
1990	153	102	48	3
1991	331	220	105	6
1992	433	288	137	8
1993	1197	796	380	22
1994	2013	1338	638	37
1995	2293	1524	727	42
1996	2599	1727	824	48
1997	2955	1964	937	55
1998	3159	2099	1001	58
1999	3261	2167	1034	60
2000	3414	2269	1082	63
2001	3516	2337	1115	65
2002	3618	2404	1147	67
2003	3694	2455	1171	68
2004	3743	2487	1186	69
2005	3893	2587	1234	72
2006	3876	2576	1229	72
2007	3973	2640	1259	73
2008	4324	2873	1371	80
2009	4598	3056	1458	85
2010	4644	3086	1472	86

Source: Made with data collected at Survey 2011, FAO Statistics 2011, Gutierrez, Obando, and Vargas, 2011

Appendix H. Grain - Parameter ν for Small Farmers

Year	Total Area Planted under New Tech (Ha)	Area Planted under New Tech by small farmers (Ha)	Grain Produced under New Tech by small farms (mT)	Total National Grain Production	ν (small Farmers)
1989	-	-	-	-	-
1990	300	120	102	366897	0.0
1991	650	260	220	269408	0.1
1992	850	340	288	344180	0.1
1993	2350	940	796	386500	0.1
1994	3950	1580	1338	332028	0.2
1995	4500	1800	1524	389072	0.2
1996	5100	2040	1727	443536	0.2
1997	5800	2320	1964	351019	0.3
1998	6200	2480	2099	351870	0.4
1999	6400	2560	2167	366141	0.4
2000	6700	2680	2269	493884	0.3
2001	6900	2760	2337	508744	0.3
2002	7100	2840	2404	617225	0.2
2003	7250	2900	2455	704476	0.2
2004	7345	2938	2487	540313	0.3
2005	7640	3056	2587	646940	0.2
2006	7607	3043	2576	575044	0.3
2007	7796	3118	2640	594297	0.3
2008	8485	3394	2873	498505	0.4
2009	9024	3610	3056	579757	0.3
2010	9113	3645	3086	515750	0.4

Source: Made with data collected at Survey 2011, FAO Statistics 2011, Gutierrez, Obando, and Vargas, 2011

Appendix I. Grain - Parameter v for Medium Farmers

Year	Total Area Planted under New Tech (Ha)	Area Planted under New Tech by medium farmers (Ha)	grainProduced under New Tech by Medium farms (mT)	Total National grainProduction	v (Medium Farmers)
1989	-	-	-	-	-
1990	300	90	48	366897	0.01
1991	650	195	105	269408	0.02
1992	850	255	137	344180	0.02
1993	2350	705	380	386500	0.04
1994	3950	1185	638	332028	0.08
1995	4500	1350	727	389072	0.08
1996	5100	1530	824	443536	0.07
1997	5800	1740	937	351019	0.11
1998	6200	1860	1001	351870	0.11
1999	6400	1920	1034	366141	0.11
2000	6700	2010	1082	493884	0.09
2001	6900	2070	1115	508744	0.09
2002	7100	2130	1147	617225	0.07
2003	7250	2175	1171	704476	0.07
2004	7345	2204	1186	540313	0.09
2005	7640	2292	1234	646940	0.08
2006	7607	2282	1229	575044	0.09
2007	7796	2339	1259	594297	0.09
2008	8485	2546	1371	498505	0.11
2009	9024	2707	1458	579757	0.10
2010	9113	2734	1472	515750	0.12

Source: Made with data collected at Survey 2011, FAO Statistics 2011, Gutierrez, Obando, and Vargas, 2011

Appendix J. Grain - Parameter ν for Large Farmers

Year	Total Area Planted under New Tech (Ha)	Area Planted under New Tech by Large farmers (Ha)	Grain Produced under New Tech by Large farms (mT)	Total National Grain Production	ν (Large Farmers)
1989	-	-	-	-	-
1990	300	90	2.82071	366897	0.001
1991	650	195	6.11154	269408	0.002
1992	850	255	7.99201	344180	0.002
1993	2350	705	22.0956	386500	0.004
1994	3950	1185	37.1393	332028	0.008
1995	4500	1350	42.3106	389072	0.008
1996	5100	1530	47.952	443536	0.008
1997	5800	1740	54.5337	351019	0.011
1998	6200	1860	58.2946	351870	0.012
1999	6400	1920	60.1751	366141	0.012
2000	6700	2010	62.9958	493884	0.009
2001	6900	2070	64.8763	508744	0.009
2002	7100	2130	66.7568	617225	0.008
2003	7250	2175	68.1671	704476	0.007
2004	7345	2203.5	69.0604	540313	0.009
2005	7640	2292	71.834	646940	0.008
2006	7607	2282.1	71.5238	575044	0.009
2007	7796	2338.8	73.3008	594297	0.009
2008	8485	2545.5	79.779	498505	0.012
2009	9024	2707.2	84.8469	579757	0.011
2010	9113	2733.9	85.6837	515750	0.012

Source: Made with data collected at Survey 2011, FAO Statistics 2011, Gutierrez, Obando, and Vargas, 2011

Appendix K. Benefits in the Dairy Market

Year	National Dairy Production (Tons)	Nominal Price $/Tons	IPC 2010=100	Producers Real Price ($/Ton)	Weighted Processors Price ($/Ton)	Margin	v	α	Ɓ	Consumer Benefits	Processors Benefits	Producers Benefits	Gross Social Benefits
1989	0	0	0	0	0	0	0.0	0	0	0	0	0	0
1990	157920	290	0.2	1810	2454	645	0.0	13	52	2931	89	720	3741
1991	165000	290	0.2	1274	1729	454	0.0	19	78	6351	193	1561	8105
1992	171000	229	0.3	775	1052	276	0.1	33	132	8305	253	2041	10599
1993	183727	249	0.4	687	931	245	0.2	39	161	22961	699	5643	29303
1994	187242	245	0.4	590	800	210	0.3	47	190	38594	1174	9484	49253
1995	187636	307	0.5	667	904	238	0.3	42	169	43968	1338	10805	56111
1996	195455	307	0.5	597	810	213	0.3	48	196	49830	1516	12245	63592
1997	209136	309	0.6	550	746	196	0.3	56	228	56669	1724	13926	72320
1998	218127	302	0.6	476	646	170	0.3	68	275	60577	1843	14886	77307
1999	500000	282	0.7	399	541	142	0.2	185	752	62533	1903	15367	79802
2000	560000	276	0.8	350	475	125	0.1	236	960	65464	1992	16087	83543
2001	564476	295	0.5	624	846	222	0.1	133	543	67419	2051	16568	86038
2002	544145	294	0.5	599	813	214	0.2	134	545	69373	2111	17048	88531
2003	571509	274	0.5	530	719	189	0.2	159	647	70838	2155	17408	90402
2004	587145	255	0.6	456	618	162	0.2	190	773	71766	2184	17636	91586
2005	614118	243	0.6	397	538	141	0.2	228	929	74648	2271	18344	95264
2006	664545	244	0.7	362	491	129	0.1	271	1102	74326	2262	18265	94853
2007	691127	257	0.7	344	466	123	0.1	296	1206	76173	2318	18719	97209
2008	718882	326	0.9	365	495	130	0.1	290	1181	82905	2523	20373	105800
2009	747809	374	0.9	408	553	145	0.1	270	1100	88171	2683	21667	112521
2010	753281	408	1.0	408	553	145	0.1	272	1108	89041	2709	21881	113631

Source: Model Results 2012.

Note: $\alpha=\eta*(Q1/P1)$ and $\beta=\gamma*(Q1/P1)$, $\eta=0.2$, and $\gamma=0.6$. Form of the shift is parallel.

Appendix L. Return in the Dairy Market

Year	Gross Social Benefits	Total Research Cost	Cumulative Research Cost	Net Social Gains	IRR
1985	-	27174	27174	-27174	20%
1986	-	13948	41122	-13948	
1987	-	15911	57034	-15911	
1988	-	24382	81416	-24382	
1989	-	28303	109719	-28303	
1990	3,740.82	7116	116834	-3375	
1991	8,105.09	7116	123950	990	
1992	10,598.94	7116	131065	3483	
1993	29,302.69	0	131065	29303	
1994	49,252.87	0	131065	49253	
1995	56,110.86	0	131065	56111	
1996	63,591.96	13587	144652	50005	
1997	72,319.93	6974	151626	65346	
1998	77,307.00	7956	159582	69351	
1999	79,802.33	12191	171773	67611	
2000	83,542.94	14151	185925	69391	
2001	86,037.64	3558	189482	82480	
2002	88,531.35	17145	206627	71387	
2003	90,401.59	10532	217159	79870	
2004	91,585.94	7956	225115	83630	
2005	95,264.08	39365	264480	55899	
2006	94,852.58	28100	292579	66753	
2007	97,209.16	19469	312049	77740	
2008	105,800.41	27940	339988	77861	
2009	112,521.48	31861	371849	80661	
2010	113,631.23	7116	378965	106516	

Source: Model Results 2012.

Appendix M. Benefits in the Grain Market.

Year	National Grain Production (Tons)	Nominal Grain Price $/Tons	IPC 2010=100	Real Grain Price $/Ton	V	α	Ɓ	Consumer Surplus (grain sales)	Consumer Surplus to Producers	Producer Surplus	Social Benefits
1985	0	0	0.0	0	0	0	0	0	0	0	0
1986	0	0	0.0	0	0	0	0	0	0	0	0
1987	0	0	0.0	0	0	0	0	0	0	0	0
1988	0	0	0.0	0	0	0	0	0	0	0	0
1989	0	0	0.0	0	0	0	0	0	0	0	0
1990	366897	113.086	0.2	704.895	0.0075	104.1	260.249	1369	628	786	2750
1991	269408	120.338	0.2	528.294	0.02212	101.992	254.979	2966	1362	1703	5959
1992	344180	127.568	0.3	432.222	0.02264	159.261	398.152	3878	1780	2227	7793
1993	386500	153.069	0.4	422.259	0.05574	183.063	457.657	10723	4922	6156	21545
1994	332028	197.249	0.4	475.32	0.10907	139.707	349.268	18023	8274	10347	36213
1995	389072	257.656	0.5	559.862	0.10604	138.989	347.471	20533	9426	11787	41256
1996	443536	235.443	0.5	457.916	0.10542	193.719	484.298	23270	10683	13359	46757
1997	351019	201.268	0.6	358.732	0.15149	195.7	489.25	26464	12149	15192	53173
1998	351870	185.609	0.6	292.525	0.16154	240.574	601.436	28289	12986	16240	56840
1999	366141	155.03	0.7	219.756	0.16025	333.226	833.064	29201	13405	16764	58673
2000	493884	200.589	0.8	254.808	0.12437	387.652	969.13	30570	14034	17550	61424
2001	508744	150.417	0.5	318.514	0.12435	319.449	798.622	31483	14453	18074	63258
2002	617225	155.134	0.5	315.738	0.10546	390.973	977.434	32395	14872	18598	65092
2003	704476	132.283	0.5	256.04	0.09435	550.286	1375.72	33080	15186	18991	66467
2004	540313	166.191	0.6	296.651	0.12463	364.275	910.689	33513	15385	19239	67338
2005	646940	197.391	0.6	322.047	0.10827	401.768	1004.42	34859	16003	20012	70043
2006	575044	178.469	0.7	264.656	0.12128	434.559	1086.4	34708	15934	19926	69740
2007	594297	251.581	0.7	337.178	0.12027	352.512	881.28	35571	16330	20421	71473
2008	498505	258.25	0.9	289.451	0.15605	344.449	861.123	38714	17773	22225	77788
2009	579757	363.196	0.9	396.502	0.1427	292.436	731.09	41174	18902	23637	82731
2010	515750	362.688	1.0	362.688	0.162	284.404	711.011	41580	19088	23870	83546

Source: Model Results 2012.

Note: $\alpha=\eta*(Q1/P1)$ and $\beta=\gamma*(Q1/P1)$, $\eta=-0.4$, and $\gamma=0.5$. Form of the shift is parallel.

Appendix N. Return in the Grain Market.

Year	Total Gross Surplus	Research Cost	Cumulative Research Cost	Net Benefits	IRR
1985	0	37972	37971.8	-37972	12%
1986	0	19491	57462.4	-19491	
1987	0	22234	79696.4	-22234	
1988	0	34070	113767	-34070	
1989	0	39549	153316	-39549	
1990	2750	9943	163259	-7192.5	
1991	5959	9943	173202	-3983.6	
1992	7793	9943	183145	-2150	
1993	21545	0	183145	21544.9	
1994	36213	0	183145	36213.5	
1995	41256	0	183145	41255.9	
1996	46757	18986	202131	27770.7	
1997	53173	9745	211876	43428.2	
1998	56840	11117	222993	45723.1	
1999	58673	17035	240028	41637.7	
2000	61424	19775	259803	41649.6	
2001	63258	4971	264774	58286.8	
2002	65092	23957	288731	41134.7	
2003	66467	14717	303448	51750.3	
2004	67338	11117	314565	56220.8	
2005	70043	55007	369572	15035.7	
2006	69740	39265	408837	30474.3	
2007	71473	27205	436043	44267.3	
2008	77788	39042	475084	38746.8	
2009	82731	44521	519605	38210.2	
2010	83546	9943	529548	73603.4	

Source: Model Results 2012