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Estimating the Potential Returns to Research and Development from Sorghum Value Added Products in El Salvador and Nicaragua

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ESTIMATING THE POTENTIAL RETURNS TO RESEARCH AND DEVELOPMENT FROM SORGHUM VALUE ADDED PRODUCTS IN EL SALVADOR AND NICARAGUA

by

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Abstract

Sorghum bicolor (L.) Moench is a drought tolerant crop able to adapt to hot and dry weather. It has excellent chemical and physical properties, which make it a grain of good quality for processing different types of products. This research is an impact assessment study that estimated the potential impacts of new uses of sorghum by using an equilibrium displacement model. The data used was drawn from interviews developed in July 2011.Using total quantity production, prices, prices elasticities and cost shares 8 potential market scenarios were simulated. Results between countries were similar. Thus, the analysis was applied for both countries. Producers gain when the sorghum flour demand is shifted between $6,000 and $ 30,000. When the feed demand curve shifted the producer benefit was between $3 million and $ 13 million. In the scenario where the sorghum grain curve shifted and the demand curve for feed and sorghum flour, producer net benefit is between $300,000 to $2.5 million. Interpreting these results suggest that increasing yield and promoting sorghum as a substitute of maize for feed and sorghum as a substitute of wheat for sorghum flour can benefit producers while helping them to increase yield.

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Dedication

The following pages are dedicated to: The development practitioners who might never have the opportunity to study a graduate degree but who know how to communicate and generate changes among poor people. And to the bottom part of the development chain, to those who did not have the opportunity to choose in which country they wanted to be born: low income people who are the subject of study in many academic programs around the world.

“You gain strength, courage and confidence by every experience in which you really stop to look fear in the face. You are able to say to yourself, 'I have lived through [this experience]. I can take the next thing that comes along.' You must do the thing you think you cannot do.”

Eleanor Roosevelt

“Trust in the Lord with all your heart and lean not on your own understanding; in all your ways acknowledge him, and he will make your paths straights.”

Proverbs 3: 5-6

Chapter 1 - Sorghum utilization and value added products

1.1 Background information on sorghum

Staple grains such as rice, maize, and sorghum are produced in developing countries where agriculture is limited by lack of knowledge, financial resources, and governance. Researchers have shown that of these three crops, sorghum has unique characteristics that make it suitable for growing in dry regions. Specifically, sorghum is a drought-tolerant multipurpose crop able to adapt to hot and dry weather. Because of this characteristic, it is used as a substitute for maize in regions of Africa, Asia, and Latin America where irrigation systems are unaffordable and water is limited. There are different varieties of sorghum that have been grouped according to their economic importance. Table 1.1 presents the scientific name of theses varieties and their different uses, whether for grain or forage purposes.

Table 1.1 Different varieties, scientific names and uses of sorghum crop

Variety	Scientific name	Uses
Kafir	*Sorghum bicolor Kaffrorum*	Grain and forage in Africa
Sweet Sorghum	*Sorghum bicolor Saccharatum Boerl.*	Grain, forage and silage
Durra	*Sorghum bicolor Durra Hubbard and Rhed.*	Grain and forage in India
Shallu	*Sorghum bicolor Roxburghii Haines*	Grain and forage
Hegari	*Sorghum bicolor (L.) Moench Hegari*	Grain and forage
Milo	*Sorghum bicolor Moench Milo*	Grain
Escobero	*Sorghum bicolor cechnicum Jav.*	Grain
Sudan Grass	*Sudanese Hitch*	Forage in Sudan
Johnson Grass	*Sorghum Halapenese (L.)*	Forage
Sorghum Almun	*Sorghum Almun Parodi*	Forage

Source: INTA 2011

From the table 1.1, we can see that grain and forage are the main uses of sorghum. Grain sorghum can be used as forage; however, forage sorghum cannot be used as grain sorghum (i.e. Sudan and Johnson grass). There is also a new variety of sorghum called Brown Mid Rib (BMR) that is more digestible because it has a lower content of lignin (the part that of the plant that the animals do not eat), which has served as both grain and forage sorghum in Central and South America. In particular, sorghum forage is used to feed dairy cows and cattle in regions where extensive production is not possible or in regions where during the winter it is necessary to feed the animals with silage. In Central America, sorghum forage is being used in countries such as El Salvador and Guatemala which have an intensive production system; however, in countries like Nicaragua, forage sorghum has just been promoted since 2010 because of the recent effects of climate change on the pasture. Moreover, sorghum grain has been used for many years for human consumption as a substitute of maize and wheat and also as a grain to produce feed for poultry, pigs, horses, and tilapia (Obando, 2011).

Considering the importance of sorghum grain for human consumption and as a cash crop in the feed industry, we focused this study on the different aspects of value- added products of sorghum grain.

1.1.1 Nutritional value of sorghum grain

To understand more about the uses of sorghum grain, it is important to first know about the nutritional value of this crop. Sorghum has excellent chemical and physical properties, which make it a grain of good quality for processing different types of products. Nutritionally, this grain is a source of protein and energy because it supplies carbohydrates and has more fat than rice and wheat. Additionally, sorghum contains iron, zinc, manganese and copper. Also, its protein structure helps to ensure the quality of various foods: snacks, porridges, flour, and also feed concentrate. Furthermore, it is gluten free and so is consumed by diabetics, and it is a substitute for wheat flour (Hamaker and Bugusu 2002).

According to Joe Hancock (2011), sorghum grain nutritional value has been subject of myths that limit its consumption in the feed industry: 1) “Sorghum grain has lower content and availability of nutrients than maize:” Compared to maize, sorghum has more mineral content but has a lower level of some amino acids and vitamins (i. e.Arginine, Histidine, Lysine) and higher level of others (i.e. Isolucine, Leucine, Trutophan and Valine). 2) “Sorghum is full of tannins and mycotoxins:” It has been shown that locally grown grains have better quality because of genetically fewer mycotoxins. 3) “Sorghum is not responsive to advanced technology:” The nutritional value of sorghum compared with maize depends on the particle size, thus grinding is very important. A particle size of 500 to 600 microns is recommended when sorghum is used for poultry feed. 4)”Seed grain color is an indication of the nutritional value of sorghum grain:” Pericarp and endosperm color do not seem to be nutritionally significant. Also, the white sorghum grain plant may be important in marketing and perception of sorghum but it has no nutritional advantages.

All these characteristics suggest similarities in nutrients and properties with other grains, which makes sorghum an attractive grain to add value ; however, sorghum is considered an inferior grain, and because of this, its consumption has not increased as has that of other grains in past years (USCP 2010).

1.2 Uses of Sorghum grain around the world

Around the world, sorghum has been used to prepare many products. For example, consumers buy sorghum paying 14 percent tax on sorghum value added products in South Africa. In Ethiopia, sorghum is consumed as Injera, a fermented pancake that has an attractive texture (Taylor 2007). In Japan, identity-preserved US sorghum grain is used to make snacks, specifically as a substitute for rice. Also, in India it is used as raw material to make bioethanol, while in Latin America, it is used mainly as a substitute for corn in the feed industry. More recently, it has been used to substitute for wheat flour in baked products. Primarily, sorghum has four different areas for classifying its value added products: Bioethanol, beer, -human food, and animal food. We will start by looking at general aspects of each of these areas.

In the ethanol market, corn and sorghum are perfect substitutes. Sorghum can be used in three types of ethanol production: Starch, sugar, and cellulosic, which results in approximately 30 to 35% of US sorghum grain production being used for ethanol purposes.

Second, in Africa, sorghum grain is used to produce opaque beer on a large scale, and the industry is growing in southern, central, and eastern Africa. In fact, beer is one of the few industrialized products in Africa. Sorghum malt is the main ingredient, and it is used in Zimbabwe and South Africa (Taylor 2007).

Third, although sorghum grain has great nutritional properties for humans, its consumption has decreased in urban areas because of the time and effort necessary to prepare sorghum food, and also because of the few marketing techniques to promote its products (Sorghum Checkoff 2011). While it is used to prepare foods for adults and children, it is not well digested by infants unless it is combined with food that contains lysine (Anglani 1998). Clearly, foods prepared with sorghum do not succeed in the market because of consumer bias against it (i.e. inconvenience, unpopular texture, poor shelf-stability). Despite this, sorghum flour is the main sorghum value added product that is increasing its marketability in Africa and is getting importance the last three years in Central America, especially in El Salvador and Nicaragua.

Ultimately, feed is the main value added product made with sorghum. Its demand drives production around the world. In fact, 80 percent of total demand for the grain comes from the

United States, Japan, Mexico, Argentina, and Venezuela (Sorghum Checkoff 2011). Central America also uses this grain for feeding animals but uses locally produced sources. It is popular in part because researchers have shown that sorghum grain has 90 to 95 percent of the feeding value of maize. It is especially favored to feed swine and poultry. Moreover, recent studies have shown that sorghum can substitute for maize 100 percent without reducing animal performance; however, in broilers' diets, 1 to 2.5 percent fat is required for sorghum to meet maize's nutritional value (Douglas et al 1990).

Sorghum flour and feed concentrate are the value added products that have the greatest potential in Central America. However, sorghum grain production in this region, specifically in Nicaragua and El Salvador, is limited due to inconsistent grain supply, unavailable processing technology, nutritional myths, and lastly and more importantly, government interventions regarding subsidized grains (i.e. maize, wheat) (Rooney 2008).

1.3 Uses of sorghum in Nicaragua

Nicaragua is a Central American country located between Honduras and Costa Rica, bordering the Pacific Ocean and the Caribbean Sea. It is one of the twenty focus countries of the U.S. government's global hunger and food security initiative, Feed the Future. According to the United States Department of State (2010), Nicaragua is the second poorest country in the Western Hemisphere with a GDP per capita of $ 1,126 dollars. It has a population of 5.6 million people over 50,336 square miles. The World Bank (2008) reports that 60 percent of poor and 80 percent of extremely poor people live in rural areas of Nicaragua. Specifically, 48 percent of its population lives below the poverty line and approximately 46 percent of the population lives on $1.15 per day. The agricultural sector represents 28 percent of the GDP and in the last two years has been affected by excessive amount of rain. The Ministry of Agriculture (2011) affirms that this sector has increased by 6.1 percent. Moreover, this sector produces 71 percent of the export products and also expects to grow 11 percent, from US$ 1,032 million in 2010 to US$ 1,431 million in 2011, thanks to new market opportunities because of the ALBA government (Alianza Bolivariana para los Pueblos de Nuestra América).

1.3.1 Overview of sorghum production in Nicaragua

Nicaraguan farmers produce crops such as coffee, white corn, cattle, vegetables and beans. On average 81 percent of farmers have subsistence production of poultry and pigs; additionally, 50 percent of all farmers produce grains and 43 percent produce cattle. According to data from the Nicaraguan Ministry of Agriculture (2010), Nicaragua has 16,388 sorghum producers divided into 14,132 small producer, 1,510 medium producers, and 746 large producers. Small farmers produce from a quarter to 5 manzanas of sorghum, and they use this crop to prepare food products during the dry season and also to feed their own animals. Moreover, the medium and large of farmers produce from 100 to 3,000 manzanas of sorghum grain yearly, and most of them sell their production to feed companies. Table 1.2 shows the total number of manzanas used to produce sorghum. In Central America, Nicaragua dedicates more land to produce just sorghum grain, and this correlates with the medium and larger farmers in that country. However, 75 percent of El Salvador sorghum production is dual, which means farmers plant corn and sorghum at the same time, and the total production it includes grain and forage.

Table 1.2 Sorghum production area and technique used in Central America

Country	Dual crop (Corn + Sorghum)		Monoculture (sorghum)		Total
	Manzanas	%	Manzanas	%	Manzanas
Nicaragua	48,654	46	57,240	54	105,894
El Salvador	101,601	75	34,344	25	135,945
Guatemala	35,775	50	35,775	50	71,550
Honduras	78,483	65	42,260	35	120,743

Source: Clara 2011

Nicaraguan farmers are associated in organizations such as National Union of Farmers and Ranchers of Nicaragua (UNAG), National Union of Associated Agricultural Producers (UNAPA) and Nicaraguan National Sorghum Producer Association (ANPROSOR). The last one is the only that has just sorghum producers; the other two have farmers with different crops. According to Francisco Vargas (2011), ANPROSOR has 180 members that on average between 2005 and 2010 produced 850,000 quintals of sorghum and had a yield of 55 qq/ manzana. However, during the last three years, the cost of production has increased from approximately US$ 232.60 in 2007 to US$ 450.00 in 2010. This means sorghum producers are facing many obstacles because the price that is paid to farmers has not increased proportionally with the cost of production; since the activity is not profitable for them, they produce less.

1.3.1.1 Sorghum production price agreement

Once a year, the Nicaraguan government meets with the producers associations and the Poultry Producer Association to fix the price that producers will be paid for their production. This price follows the international price of corn. Accordingly, the Poultry Producer Association, which represents the feed industry, agrees to buy a certain amount of grain in order to import yellow corn from the United States at a zero percent tariff. Five companies form this association: Cargill (Tip top Industrial and Pipasa), La Estrella, MONISA, Avicola La Barranca, and El Granjero. Each company has to buy a specific percentage of the total production, and this percentage is established by the scale of the company. Table 1.3 shows the quantities of sorghum grain that each Poultry company has to buy in order to be able to import maize at zero percent tariff.

Table 1.3 Percentage and quantities of sorghum bought by the Nicaraguan Poultry companies

Companies	Participation		Sorghum companies proportions 2011/2012 (qq)
	Base ANAPA	Adjusted with APEMEPA	
Tip Top Industrial	28.50%	26.10%	390,768
PIPASA Corporation	20.80%	19.00%	285,192
Avicola La Estrella (AVESA)	21.50%	19.70%	294,790
Molinos de Nicaragua S.A. (MONISA)	17.00%	15.50%	233,090
Concentrados El Granjero	5.50%	5.00%	75,411
Avicola La Barranca	4.20%	3.80%	57,587
Industrias San Francisco	2.40%	2.20%	32,907
APEMEPAN	9.50%	8.70%	130,256
Total	**109.40%**	**100.00%**	**1,500,001**

Source: ANAPA 2009

The utilization of sorghum in Nicaragua is regulated by this yearly agreement, and consequently, the price of sorghum will fluctuate in local markets, influencing other users (i.e. sorghum flour users).

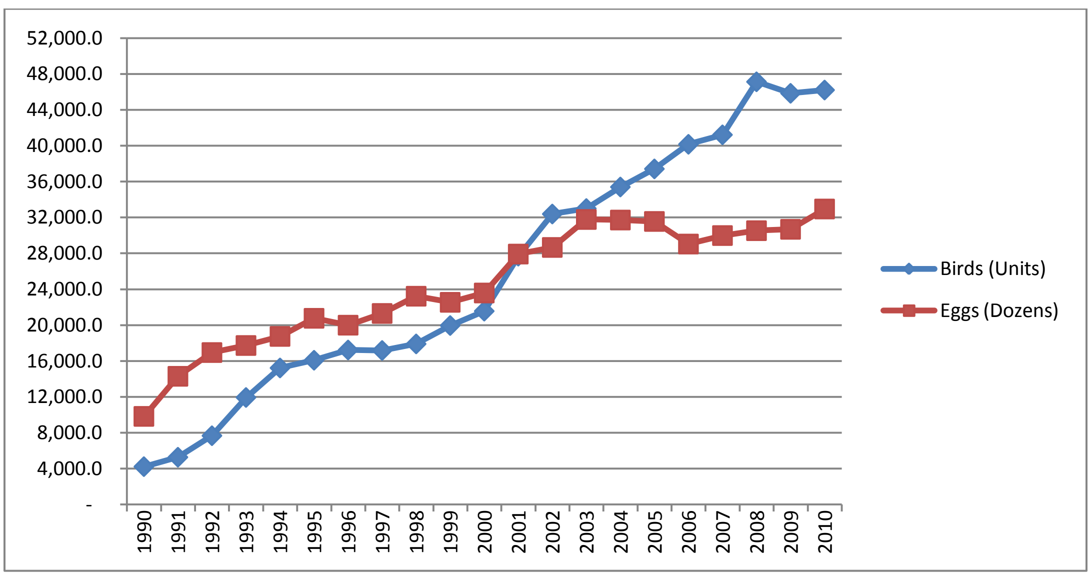
1.3.2 Feed Industry in Nicaragua

The Feed Industry in Nicaragua is led by the Poultry companies' members of ANAPA. Because Nicaraguans have low income and poultry meat has a low price, poultry consumption has been increasing between 1990 and 2010. As a consequence, the poultry companies are producing more poultry meat and eggs, as graph 1.1 shows. According to Alfredo Velez, Vice-President of Tip Top International (2011), the poultry sector increased 17 percent from 2009 to 2010, due to a free market that has favored producers and consumers with better prices; thus, in 2009, companies sold 33 million more pounds. During 2010, the companies invested in improving the feed plants and production logistics.

The international price of maize and soybean increased the cost of production of poultry companies, largely because these two grains are imported from the United States because there is not enough local grain production. Yearly, the feed plants need 3.6 million quintals of grain; but from the agreement companies should receive 1.5 million quintals of sorghum grain. However, at the harvest period and because of the low price paid to producers, sorghum producers just sell half of what they sign in the agreement. Javier Solorzano, The Ministry of Industry (2011) affirms that the government is working with the sorghum producers to increase the level of production in order to reduce the purchase of imported grain.

In March 2011, the government of the United States donated 240,000 quintals of maize and 90,000 quintals of soybean flour; however, the government sold it to the poultry companies at almost the same price as the international price. So, the government did not help to reduce the cost of production.

Figure 1.1 Poultry production in Nicaragua



Source: Nicaraguan Central Bank

The Poultry sector has been growing quickly with companies such as Cargill having invested US$ 30 million since 2000 and promising to invest US$ 27 million in the next 5 years. Meanwhile, MONISA is investing 3.5 million in 2011.

1.3.3 Bakery industry in Nicaragua

According to the MIFIC (2004) Nicaragua has 1,901 bakeries, each with, on average 4 employees. The total industry has on average 7,700 bakeries, and 33 percent of them are family run. In 2003, the monthly salary was US$ 51.63.

According to MIFIC and Narvaez (2002) the majority of the bakeries are artisanal. Approximately 94 percent of them use wood ovens, 4 percent gas stove and 2 percent electric ovens. Additionally, 88 percent of the bakeries do not have a private brand and they package the bread in plastic bags without labels. These bakeries produce white bread and sweet bread. Additionally, tortillas, green bananas and plantains affect the demand for bakery product, so bakers cannot raise the price of white bread because consumers will not buy it. There are 5 companies that control the wheat imports: Harinisa, MONISA and Agricorp (Gemina, Proharina, and Fahcasa). These companies have wheat mills and export to bordering countries.

In particular, in Nicaragua, sorghum flour is used as a substitute for wheat in small bakeries because the wheat flour prices are usually controlled by an oligopsony of three companies MONISA, Agricorp, and Harinasa. Additionally, the Nicaraguan Technology Center (INTA) has been promoting sorghum flour since 2009 and currently has two bakery groups that have adopted new processing technology.

1.4 Uses of sorghum grain in El Salvador

El Salvador is located in Central America between Guatemala, Honduras, and the Pacific Ocean. It is the country with the highest population density in the Western Hemisphere; it has a population of 7.2 million. The GDP per capita is $7,300 dollars, and the main economic activity is services at 59 percent of the GDP. After Costa Rica and Panama, El Salvador has the third most developed economy of Central America.

The agriculture sector has been limited because of 12 years of civil war and land ownership conflicts. It is divided into, the following sub-sectors: Staple crops 21 percent, cattle 18 percent, poultry 14 percent, coffee 11 percent, forestry 6 percent, fishery 4 percent, and others 21 percent. Because in El Salvador land is a very limited resource, Salvadorian producers are small and on average, staple grain farmers produce on 3 manzanas (Angel 2008). The major grains are rice, white corn, and sorghum grain. Most of the small producers are classified as subsistence farmers; they either keep all their production for their own consumption or keep part of it and sell the rest. According to the General Direction of Agricultural Economics (2007), 28 percent of the country's white corn production as well as, 22 percent of sorghum production and 21 percent of beans production are produced for self-consumption.

1.4.1 Overview on sorghum production

According to the census of Agriculture (2007/2008), El Salvador has 96,157 sorghum producers. Table 1.2 shows that 75 percent of all farmers produce sorghum and white corn together. When the corn is harvested then the sorghum plant grows and is harvested between December and January. Interestingly, El Salvador has more sorghum producers than Nicaragua but does not have a sorghum producer association.

The same table shows that 25 percent of farmers produce just produce sorghum, but in this case, farmers will have cattle, poultry or pigs, and they use the sorghum as grain or for forage to feed their animals. In El Salvador, no farmers produce sorghum as their main activity. Overall, in the production cycle 2010/2011, the total sorghum production in El Salvador was

2,343, 645 quintals. Table 1.4 presents the area, total quantity production and yield of the sorghum crop in El Salvador from the production cycle 2000/2001 to 2010/2011. Compared to Nicaragua, El Salvador produces more sorghum; however, the data presented in this table do not differentiate from forage and grain purposes.

Table 1.4 Sorghum area, production and yield in El Salvador

Year	Area (mz)	Production (qq)	Yield (qq/mz)
2000/2001	134,200	3,239,500	24.1
2001/2002	139,228	3,273,910	23.5
2002/2003	109,124	3,061,593	28.1
2003/2004	126,174	3,101,193	24.6
2004/2005	146,175	3,753,353	25.7
2005/2006	123,662	2,873,533	23.2
2006/2007	92,051	1,895,019	20.6
2007/2008	120,629	2,840,635	23.5
2008/2009	138,100	2,958,065	21.4
2009/2010	136,632	3,601,359	26.4
2010/2011*	119,676	2,343,645	19.6

Source: Ministry of Agriculture 2011

1.4.1.1 Sorghum production price agreement

In order to spur incentive to produce and commercialize sorghum grain, the government of El Salvador established in 2003 a yearly agreement in which the price that sorghum producers will be paid is fixed. The objective of this agreement is that the Salvadorian Feed Industry consumes more of the local grain in order to help local farmers instead of importing yellow grain from the US. The agreement is developed among the producers, the Feed Industry representing by the Salvadorian Poultry Association (AVES), the Agricultural Board of Trade of El Salvador (BOLPROES), and the government representing by the Ministry of Agriculture. According to Manuel Sosa, Technician in the policy and Sector Planning Division of MAG (2011), the government receives the names of the producers willing to sell their produce and then, after checking them, the government sends the information to BOLPROES, which will communicate to the industry the total amount of sorghum available for the specific year. Around 60 and 62 companies will buy sorghum and approximately 15 agricultural producer groups will sell their product. Sosa affirms that according to the agreement the industry states its intent to buy every year by the last week of March, and then BOLPROES receives the names of producers and their production quantities by October 15 and by December 15 prepares the different buy and sell contracts. The industry members receive the grain by December 31.

The price is fixed based on the price of US yellow corn No. 2 on the future market of the Chicago Board of Trade. According to Agustin, AVES president (2011), the price formula is equal to the: Average of December corn price + shipping cost + 15% tax. The characteristics of sorghum grain that the industry requires are as follows: white grain, 13 percent of humidity, 2 percent dirt. For this agreement, companies buy only white sorghum and they do not accept forage sorghum. Sosa (2011) affirms that the industry pays 50 cents for each metric ton of imported yellow corn, approximately 472,000 metric tons representing almost 10 million quintals. This money goes to the Fund for Competitiveness and Restructuring the Agricultural and Agro industrial sector (FOCAGRO).

Interestingly, Sosa (2011) affirms that Nicaragua's sorghum production is affecting the sorghum price in El Salvador because consumers are importing the Nicaraguan overproduction. However, Donald Tuckler, President of the Nicaragua Poultry Association (2011), affirms that there is not enough sorghum supply, and if farmers produce more, companies will buy more. Additionally, table 1.5 shows that in 2007/2008 and 2008/2009 there was not sorghum grain commercialized through BOLPROES.

Table 1.5 Salvadorian sorghum grain agreement from 2000 to 2012

Year	Contracted quantity (Industry) (qq)	Quantity received (producers) (qq)	Agreement Price (US$/qq)
2000-2001	402,282	79,697	0.00
2001-2002	217,582	210,016	0.00
2002-2003	545,937	178,703	0.00
2003-2004	160,869	35,973	0.00
2004-2005	269,843	236,810	0.00
2005-2006	177,998	133,984	7.98
2006-2007	25,635	2,070	7.94
2007-2008	0	0	10
2008-2009	0	0	13.25
2010-2010	234,231	233,359	12.25
2011-2012	0	0	12.25

Source: BOLPROES 2011

1.4.2 Feed Industry in El Salvador

Similarly to Nicaragua, El Salvador feed industry is closely related to the Poultry Industry. Poultry production (meat and eggs) is greater that the production of beans and rice and it represents approximately the 70 percent of the total meat production. Salvadorian Poultry Industry export to Guatemala and Honduras frozen chicken, processed chicken products, poultry feed and eggs. Table 1.6 shows that the poultry production has been increasing, as well as the price that producers received per pound sold.

Table 1.6 Poultry production, producer prices and consumers price in El Salvador from 2000 to 2010

Year	Poultry production (pounds)	Producer price per pound	Consumer price per pound
2000	165,600,000	$0.70	$1.00
2001	161,113,600	$0.69	$0.97
2002	170,822,400	$0.69	$0.97
2003	186,540,800	$0.66	$0.91
2004	202,644,400	$0.66	$0.91
2005	216,973,200	$0.71	$0.97
2006	223,079,100	$0.74	$1.00
2007	235,000,000	$0.82	$1.11
2008	203,300,000	$1.06	$1.43
2009	215,000,000	$1.06	$1.43
2010	230,630,000	$1.06	$1.43

Source: AVES 2011

1.5 The Sorghum, Millet and Other Grains CRSP Project

The Sorghum, Millet and Other Grains (SMOG) Collaborative Research Program (CRSP) is a collaborative research program between researchers in the United States, Africa, and Latin America funded by the U.S. Agency for International Development (USAID). It was formerly known as the International Sorghum and Millet CRSP and is still commonly referred to as ”INTSORMIL.” The acronym of "INTSORMIL" is used for historical reasons and is synonymous with “SMOG”. Three specific objectives of the project are as follows: 1) “Facilitate the growth of rapidly expanding markets for sorghum and pearl millet; 2) Improve the food and nutritional quality of sorghum and pearl millet to enhance marketability and consumer health; 3) Develop effective partnerships with national and international agencies engaged in the improvement of sorghum and pearl millet production and the betterment of people dependent on these crops for their livelihoods.” In recent years, INTSORMIL has recognized the importance of expanding new markets for sorghum through developing new products made of sorghum. These products promote sorghum as a cash crop and therefore help farmers to increase their income and in the long run reduce poverty.

1.6 Study objectives and approach

An impact assessment study is the tool use to measure the impact of project activities, and it provides objective results to show donors the benefits that their funding generated in a specific period. Furthermore, it provides lessons to improve weak areas and to allocate more resources in areas requiring strengthening. Therefore, we conducted an impact assessment study to estimate the returns to Research and Development from new uses of sorghum. Specifically, the goal of this study is to measure the potential benefits that sorghum farmers will receive if the demand for value added products such as feed concentrate and sorghum flour increases in Nicaragua and El Salvador. We do this by analyzing the current situation of those products in both counties, and by using an equilibrium displacement model that estimates percentage changes in prices and quantities of sorghum grain and sorghum new uses.

1.7 Thesis organization

Chapter two presents literature about equilibrium displacement models and how they can be used to assess the impacts of research and development. In chapter three, we present the methodology used for this research. We explain the data collection, sources and calculations. Then the theoretical framework to estimate the returns of research and development is explained, and we describe the variables used in the framework. Chapter four presents the different scenarios simulated with the equilibrium displacement model and a summary of the results. Finally, Chapter five presents our conclusions, recommendations and future research opportunities of this study.

Chapter 2 - Estimating the potential returns

2.1 Benefits from agricultural research and development

The improvement of agricultural productivity has been the interest of researchers and policy makers who want to increase yield without using more resources (i.e. land). Traditionally, governments fund agricultural research and development studies because of the need to improve countries' output to assure food security and availability of raw material for other industries. The amount of money invested in this type of study was higher in the past than nowadays mainly because the development achieved during the last three centuries was thanks to the release of new seed varieties and because farmers were willing to adopt the new technology because of government incentives. Usually, countries with higher income are the ones that invest the most. For example, developed countries like New Zealand, the United States, the Netherlands and the United Kingdom contribute approximately 40 percent of the total world investment. Meanwhile, governments in developing countries have to be assisted by International Organizations to be able to invest in this type of study. As a consequence, rich countries have achieved higher agricultural productivity, and therefore, government funds are allocated to do research on topics such as natural resources, food safety, food processing technologies and human nutrition. This is not the case in developing countries where the main focus is in increasing yield to the point that the market does not matter; it is more important to have enough supply. This is because if farmers produce, the demand will follow them. Alston and Pardey (1995) introduced the concept that farmers will gain more if research and development were to focus on ways to add value to commodities. Whether this happens at the commodity level or as value added product, it is important to estimate the benefit that producers will gain from this type of investment.

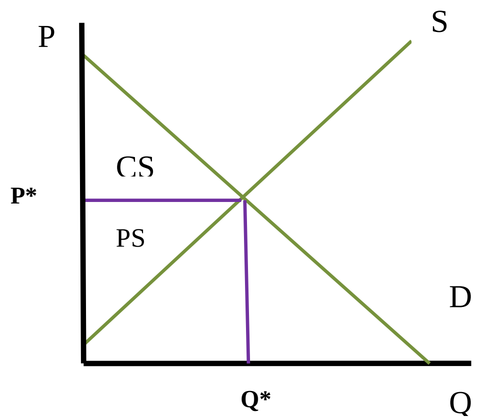
As a consequence of the introduction of a new technology, output prices decrease and consumer benefit increases while producers also receive more benefit because their variable costs decrease. The benefit for society of R&D is measured several ways. First, researchers can use the ex-ante approach in which the potential benefits are estimated based on a model that simulates different scenarios that might occur to reasonably speculate if the future investment is worthy or not. Second, the ex-post approach is used after new technology is implemented to measure the effects and to suggest a re-direction of the policy.

Whether ex-ante and ex-post, different methodologies can be used to measure the economic impact. For example, replication of original studies, bibliometrics, case study, user evaluations, benefit-cost analysis, regression analysis, operations research modeling (Data envelopment analysis), and economic simulation are all viable methods. Ultimately, when measuring the benefit for producers and consumers, the best way is to apply the Welfare Economics and use economic surplus techniques.

2.2 Economic surplus method of measuring research and development benefits

Among the different ex-ante methodologies used to measure the potential returns of research and development investments, economic surplus is the one that estimates the effects on producer surplus and consumer surplus. This approach is explained as follows: In a competitive market where there are no barriers to entry and firms want to maximize profits, the aggregate supply and demand curve intercept in a point called “equilibrium,” which represents the best combination of price and quantity that benefits consumer demand and firms; in other words, quantity demanded by consumers is supplied by the market firms. Figure 2.1 shows that at a price P* firms produce the quantity Q* in order to maximize profits because price is equal to marginal cost. The area above the supply curve and below the horizontal line of the equilibrium price line called producer surplus, which is “the difference between what producers receive when selling a product and the amount they would be willing to accept for one unit of a good”. This figure also presents consumer surplus, which represents the benefit that consumers receive.

Figure 2.1Consumer and producer surplus



Basically, three reasons make the demand curve shift: Change in income, change in the prices of substitutes or complements, changes in consumer preferences. The supply curve shifts because the technology changes, input price changes, or the number of producers changes. As mentioned in the above section, investments in research and development generate a change in technology; therefore, the supply curve shifts and the market finds a new equilibrium price P** and quantity Q** as shown in Figure 2.2. In this new equilibrium, the price is lower and the quantity is higher; therefore, producers lose surplus and it is transferred to consumers.

Figure 2.2 Shift in supply curve

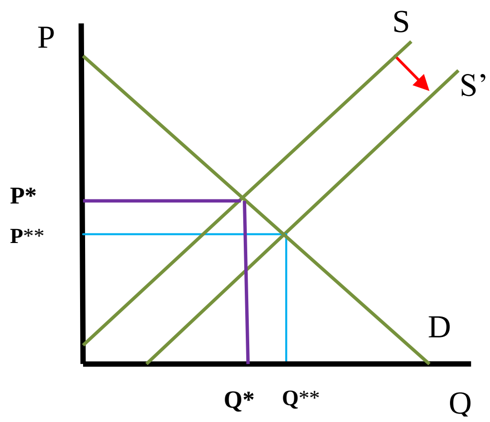
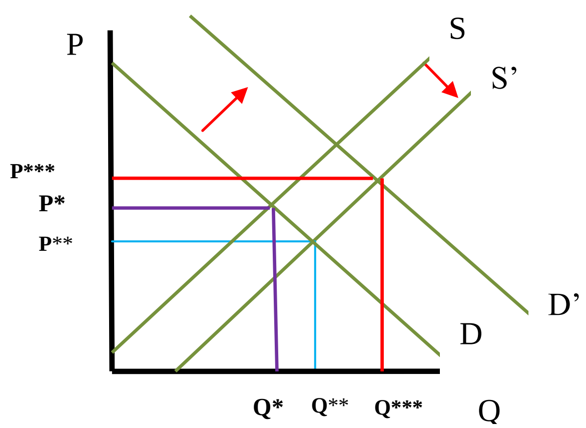


Figure 2.3 Shift in supply and demand curve



In the case where the demand curve also shifts, both curves find a new price P*** and quantity Q*** that is higher than the normal equilibrium. In order to shift the demand curve of a commodity, it is necessary to promote its demand by adding value to the commodity.

2.3 Equilibrium displacement model

Since Muth in 1964, equilibrium displacement models (EDM) have been used for measuring the impacts of "exogenous shocks" on the supply and demand curves. According to Pendell et. al 2010 an EDM is a "linear approximation" of a group of supply and demand equation representing the equilibrium. According to Henderson et al. (2010) ED models typically characterize an industry through a set of supply, demand, and market clearing functions specified with general functional forms.

The set of equations is presented in terms of elasticities and percentages changes of prices and quantities. Pendell et all (2010) also suggest that the model and it results are more accurate if the “exogenous shocks” are small. In the past this model was just used to measure the impacts of shifting the supply curve in single market; however now is used to measure the impacts along the marketing chains. The main variable needed to run an EDM is the elasticity of supply and demand. Elasticities can be obtained from literature or estimated (Pendell et al 2010)For instance, Alston and Mullen (1992) estimate economic returns to Australian wool producers from farm level and processor level R&D. Also, Zhao et al. (2003) develop a multi-sectoral ED Model for the Australian wine industry to estimate the potential returns from productivity-enhancing research and promotional investments.

Moreover, an advantage of this model is that is used mostly when researchers would like to measure the impact of an action before implementing it, and when data is limited. For example, previous studies used this model to measure the impact of trade policies in commodity markets, also the effects of research and development from the supply perspective and the demand perspective. Recently, Pendell et al. (2010) used an EDM to estimate the benefit of implementing an “animal identification and tracing system” in the meat industry. The US was affected by the restrictions that meat importing countries put on US meat because of the “bovine spongiform encephalopathy,” so maybe by implementing a system that avoids this type of contamination along the supply chain, the US can prevent this situation in the future. At any rate, the EDM estimates changes in prices and quantities and the benefits for producers and consumers simulated in different scenarios based on the National Animal Identification System.

In particular, the meat industry is modeled as a series of primary and derived demand and supply relationships within the farm-retail marketing chain.

2.3.1 Our approach

There different studies that use a multimarket system to model different scenarios using an ex-ante approach. For example, Balagtas and Kim (2007) developed an EDM to analyze effectiveness of producer-funded advertising across dairy product and milk markets. Henderson et al. (2010) studied the "Potential Payoff from R&D in the coconut Industry or North Sulawesi, Indonesia." The authors estimated the economic impacts of investments in research and development of the coconut industry. As mentioned before, the data requirements of an EDM allowed the authors to use this model to simulate different scenarios of a "vertically interrelated market."

Balagtas et al. (2003) conducted an ex ante economic analysis using an equilibrium displacement model to measure the potential benefits of new uses of whey. The authors used parameters estimated from the agricultural economics literature and data from the industry to build a model to examine changes in quantities of the milk and dairy products, and to observe the effects on whey protein. The study simulated different rates of adoption (low, medium and high) and used different prices elasticities and cost shares as the parameters of the model. We base our model on the Balagtas et al. framework.

Chapter 3 - Methodology

This chapter presents the data and methodology used in the model developed for this research. The data were drawn from our field work in Nicaragua and El Salvador partly because of a lack of available published information about the uses of sorghum grain. The outline of the chapter is as follows: Section 3.1 explains the theoretical framework; section 3.2 presents the description of the variables; section 3.3 data collection; section 3.4 presents the data sources and values used in the model.

3.1 Theoretical framework

The equilibrium displacement model (EDM) is an effective approach to estimate the potential markets effects on investments in Research and Development (Alston et al., 1995). This model is especially useful for developing an ex-ante economic analysis of developing countries, where historical data is usually less available (Takeshima, 2008). Accordingly, EDM is the model used in this research, given the limited data obtained for the region of study

The assertions on which we built our model are as follows: 1) Markets are perfectly competitive. 2) The market is assumed to have fixed proportions in production. 3) Marginal cost for quantity demanded for sorghum flour and quantity demanded for feed may differ, but both depend on the farm price of sorghum.

Following Balagtas et al. the model functional form initially starts with the following set of equations:

$Q_i^{sf} = g_i^{sf}(P_i^{sf}, \theta_i)$ *Demand for sorghum flour* (1)

$Q_i^{f} = g_i^{f}\left(P_i^{f}, P_i^{c}\right)$ *Demand for feed* (2)

$P_i^{sf} = C_i^{sf}(P_i^{s})$ *Price of sorghum flour* (3)

$P_i^f = C_i^f(P_i^s)$ *Price of feed* (4)

$Q_i^{s,sf} = \omega_i^{sf} * Q_i^{sf}$ *Quantity demanded of sorghum used in sorghum flour* (5)

$Q_i^{s,f} = \omega_i^f * Q_i^f$ *Quantity demanded of sorghum used in feed* (6)

$Q_i^s = Q_i^{s,sf} + Q_i^{s,f}$ *Total quantity demanded of sorghum from country i* (7)

$Q_i^s = g_i^s(P_i^s, Z_i)$ *Total quantity demanded of sorghum* (8)

Where *i* refers to each country (Nicaragua or El Salvador); *sf* denotes sorghum flour; *f* denotes feed; Q_i^{sf} represents demand for sorghum flour; Q_i^f is demand for feed; $Q_i^{s,sf}$ is quantity demanded of sorghum used in sorghum flour; ω_i^{sf} is constant share of demand for sorghum flour; $Q_i^{s,f}$ is quantity demanded of sorghum used in feed; ω_i^f is constant share of demand for feed; $Q_i^{sf,f}$ represents total quantity demanded of sorghum from country *i; * P_i^{sf} is price of sorghum flour; P_i^f is price of feed; P_i^s is farm price of sorghum grain; P_i^c is price of corn; θ_i is demand shifter for sorghum flour; and Z_i is sorghum supply shifter.

The functional form equations were changed to the log differential form using the following steps: First, equations (1), (2), (3), (4) and (8) were transformed by taking their total differential:

$$dQ_i^{sf} = \frac{\partial f_i^{sf}}{\partial P_i^{sf}} dP_i^{sf} + \frac{\partial f_i^{sf}}{\partial \theta} d\theta_i^{sf} \quad (1')$$

$$dQ_i^f = \frac{\partial f_i^f}{\partial P_i^f} dP_i^f + \frac{\partial f_i^f}{\partial P_i^c} dP_i^c \quad (2')$$

$$dP_i^{sf} = \frac{\partial C_i^{sf}}{\partial P_i^s} dP_i^s \quad (3')$$

$$dP_i^f = \frac{\partial C_i^f}{\partial P_i^s} dP_i^s \quad (4')$$

$dQ_i^s = \frac{\partial g_i^s}{\partial P_i^s} dP_i^s + \frac{\partial g_i^s}{\partial \theta} d\theta_i^s$ (8')

Where d denotes the absolute change in quantities and prices of its respective country. Multiplying both sides of equations (1'), (2'), (3'), (4'), and (8') by $\frac{1}{Q_i^{sf}}, \frac{1}{Q_i^f}, \frac{1}{P_i^{sf}}, \frac{1}{P_i^f}, \frac{1}{Q_i^s}$, respectively. Finally, the equations were expressed in terms of log differentials yields:

$$\frac{dQ_i^{sf}}{Q_i^{sf}} = \frac{\partial f_i^{sf}}{\partial P_i^{sf}} \frac{dP_i^{sf}}{Q_i^{sf}} + \frac{\partial f_i^{sf}}{\partial \theta} \frac{d\theta_i^{sf}}{Q_i^{sf}} \quad (1'')$$

$$\frac{dQ_i^f}{Q_i^f} = \frac{\partial f_i^f}{\partial P_i^{sf}} \frac{dP_i^f}{Q_i^{sf}} + \frac{\partial f_i^f}{\partial P_i^c} \frac{dP_i^c}{Q_i^f} \quad (2'')$$

$$\frac{dP_i^{sf}}{P_i^{sf}} = \frac{\partial C_i^{sf}}{\partial P_i^s} \frac{dP_i^s}{P_i^{sf}} \quad (3'')$$

$$\frac{dP_i^f}{P_i^f} = \frac{\partial C_i^f}{\partial P_i^s} \frac{dP_i^s}{P_i^f} \quad (4'')$$

$$\frac{dQ_i^s}{Q_i^s} = \frac{\partial g_i^s}{\partial P_i^s} \frac{dP_i^s}{Q_i^s} + \frac{\partial g_i^s}{\partial P_i^c} \frac{dZ_i}{Q_i^s} \quad (8'')$$

The next step was to multiply the right hand side of equation (1'') by $\frac{P_i^{sf}}{P_i^{sf}}$ and $\frac{\theta_i^{sf}}{\theta_i^{sf}}$; multiply the right hand side of equation (2'') by $\frac{P_i^{sf}}{P_i^{sf}}$ and $\frac{P_i^c}{P_i^c}$; multiply the right hand side of equation (3'') by $\frac{P_i^s}{P_i^s}$; multiply the right hand side of equation (4'') by $\frac{P_i^s}{P_i^s}$; and multiply the right hand side of equation (8'') by $\frac{P_i^s}{P_i^s}$ and $\frac{Z_i}{Z_i}$, to obtain the equations in the form shown below:

$$\frac{dQ_i^{sf}}{Q_i^{sf}} = \frac{\partial f_i^{sf}}{\partial P_i^{sf}} \frac{P_i^{sf}}{Q_i^{sf}} \frac{dP_i^{sf}}{P_i^{sf}} + \frac{\partial f_i^{sf}}{\partial \theta} \frac{\theta_i^{sf}}{Q_i^{sf}} \frac{d\theta_i^{sf}}{\theta_i^{sf}} \quad (1''')$$

$$\frac{dQ_i^f}{Q_i^f} = \frac{\partial f_i^f}{\partial P_i^f} \frac{P_i^f}{Q_i^f} \frac{dP_i^f}{P_i^f} + \frac{\partial f_i^f}{\partial \theta} \frac{P_i^c}{Q_i^{sf}} \frac{dP_i^c}{P_i^c} \quad (2''')$$

$$\frac{dP_i^{sf}}{P_i^{sf}} = \frac{\partial C_i^{sf}}{\partial P_i^s}\frac{P_i^s}{P_i^{sf}}\frac{dP_i^s}{P_i^s} \qquad (3''')$$

$$\frac{dP_i^f}{P_i^f} = \frac{\partial C_i^f}{\partial P_i^s}\frac{P_i^s}{P_i^f}\frac{dP_i^s}{P_i^s} \qquad (4''')$$

$$\frac{dQ_i^s}{Q_i^s} = \frac{\partial g_i^s}{\partial P_i^s}\frac{P_i^s}{Q_i^s}\ \frac{dP_i^s}{P_i^s} + \ \frac{\partial g_i^s}{\partial P_i^c}\frac{Z_i}{Q_i^s}\ \frac{dZ_i}{Z_i} \qquad (8''')$$

Lastly, the above five equations were expressed in terms of elasticities and proportional changes, where E represents the proportional changes in prices and quantities. (e. g. E(x)= $\frac{dx}{x}$)

$$E(Q^{sf}) = \ \eta^{sf}\ E(P^{sf}) + \ \Psi \qquad (1'''')$$

$$E(Q^{f}) = \ \eta^{f}\ E(P^{f}) + \ \boldsymbol{\Gamma} \qquad (2'''')$$

$$E(P^{sf}) = \ \alpha^{sf}\ E(P^{s}) \qquad (3'''')$$

$$E(P^{f}) = \ \alpha^{f}\ E(P^{s}) \qquad (4'''')$$

$$E(Q^S) = \varepsilon_S E(P^S) + \ \mu \qquad (8'''')$$

Meanwhile, equations (5), (6) and (7) were treated with the following steps: Using the natural log properties, equation (5) was converted as follows:

$$lnQ_i^{s,sf} \ = \ ln\omega_i^{sf} \ + \ lnQ_i^{sf}$$

$$dlnQ_i^{s,sf} \ = \ dln\omega_i^{sf} + d\ lnQ_i^{sf}$$

$$dlnQ_i^{s,sf} \ = \ dln\omega_i^{sf} + d\ lnQ_i^{sf}$$

Then the equation was multiplied by $\frac{1}{Q_i^{s,sf}}$

$$\frac{dQ_i^{s,sf}}{Q_i^{s,sf}} = 0 + \frac{dQ_i^{sf}}{Q_i^{sf}}$$

Finally, the equation is shown in its elasticity form:

$$E(Q^{S,S1}) = \ E(Q^{S1}) \qquad (5')$$

Following the same steps as above, equation (6) was converted using the natural log properties.

$$lnQ_i^{s,f} = ln\omega_i^f + lnQ_i^f$$

$$dlnQ_i^{s,f} = dln\omega_i^f + d\, lnQ_i^f$$

$$dlnQ_i^{s,f} = dln\omega_i^f + d\, lnQ_i^f$$

$$\frac{dQ_i^{s,f}}{Q_i^{s,f}} = 0 + \frac{dQ_i^f}{Q_i^f}$$

Finally, the equation is shown in its elasticity form:

$$E(Q^{s,f}) = E(Q^f) \quad (6')$$

Equation 7 is

$$Q_i^s = Q_i^{s,sf} + Q_i^{s,f}$$

$$dQ_i^s = dQ_i^{s,sf} + dQ_i^{s,f}$$

Then, it was multiplied by $\frac{1}{Q_i^s}$

$$\frac{dQ_i^s}{Q_i^s} = \frac{dQ_i^{s,sf}}{Q_i^s} + \frac{dQ_i^{s,f}}{Q_i^s}$$

Multiplied by $\frac{Q_i^{s,sf}}{Q_i^{s,sf}}$ and $\frac{Q_i^{s,f}}{Q_i^{s,f}}$

We know $\Phi = \frac{Q_i^{s,sf}}{Q_i^s}$ and $(1 - \Phi) = \frac{Q_i^{s,f}}{Q_i^s}$.

Finally, the equation is shown in its displaced form:

$$E(Q^s) = \Phi\, E(Q^{s,sf}) + (1 - \Phi)E(Q^{s,f}) \quad (7')$$

In summary, the following set of equations described the model used in this research:

$$E(Q^{sf}) = \eta^{sf} E(P^{sf}) + \Psi \qquad (1'''')$$

$$E(Q^{f}) = \eta^{f} E(P^{f}) + \boldsymbol{\Gamma} \qquad (2'''')$$

$$E(P^{sf}) = \alpha^{sf} E(P^{s}) \qquad (3'''')$$

$$E(P^{f}) = \alpha^{f} E(P^{s}) \qquad (4'''')$$

$$E(Q^{S,S1}) = E(Q^{S1}) \qquad (5'''')$$

$$E(Q^{s,f}) = E(Q^{f}) \qquad (6'''')$$

$$E(Q^{s}) = \Phi\, E(Q^{s,sf}) + (1-\Phi)E(Q^{s,f}) \qquad (7'''')$$

$$E(Q^{s}) = \varepsilon_{s} E(P^{s}) + \mu \qquad (8'''')$$

Equations (1’) to (8’) are expressed in matrix form as **J X = Y** where **J** embodies all cost shares, elasticities of demand and supply, and the share in sorghum used. Meanwhile, **X** contains all the proportional changes of quantities and prices, and **Y** has the supply and demand curve shifters.

$$J = \begin{bmatrix} 1 & -\eta_{S1} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & -\eta_{S0} & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & -\alpha_{S1} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & -\alpha_{S0} & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & -\phi & (\phi-1) & 1 \\ 0 & 0 & 0 & 0 & -\varepsilon_{S} & 0 & 0 & 1 \end{bmatrix} \quad \boldsymbol{X} = \begin{bmatrix} \boldsymbol{E(Q^{S1})} \\ \boldsymbol{E(P^{S1})} \\ \boldsymbol{E(Q^{S0})} \\ \boldsymbol{E(P^{S0})} \\ \boldsymbol{E(P^{S})} \\ \boldsymbol{E(Q^{S,S1})} \\ \boldsymbol{E(Q^{S,S0})} \\ \boldsymbol{E(Q^{S})} \end{bmatrix} \quad Y = \begin{bmatrix} \psi \\ \Gamma \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ \mu \end{bmatrix}$$

The system is reducible. First, equations (5’’’’) and (6’’’’) were included in equation (7’’’’). Then, we put equation (3’’’’) into (1’’’’) and (4’’’’) into (2’’’’), incorporated into:

$$E(Q^{sf}) = \eta^{sf} \alpha^{sf} E(P^{s}) + \Psi \qquad (1^*)$$

$$E(Q^{f}) = \eta^{f} \alpha^{f} E(P^{s}) + \boldsymbol{\Gamma} \qquad (2^*)$$

$$E(Q^s) = \Phi\, E(Q^{s,sf}) + (1-\Phi)E(Q^{s,f}) \qquad (7^*)$$

$$E(Q^s) = \varepsilon_s E(P^s) + \mu \qquad (8^*)$$

The system was reduced further by substituting (1*) and (2*) into (7*)

$$E(Q^s) = (\Phi\, \eta^{sf} \;\; \alpha^{sf}\; E(P^s) + \Psi) \;\; + (1-\Phi)\, \eta^{f} \;\; \alpha^{f}\; E(P^s) + \boldsymbol{\Gamma} \qquad (7^{**})$$

$$E(Q^s) = \varepsilon_s E(P^s) + \mu \qquad (8^{**})$$

Re-arranging terms yields,

$$(\, \eta^{sf}\; \alpha^{sf} - \;(1-\Phi)\, \eta^{f}\;\; \alpha^{f}\;\;)E(P^s) + E(Q^s) = \Phi\, \Psi \;\; + (1-\Phi)\, \boldsymbol{\Gamma} \qquad (7^{**})$$

$$E(Q^s) - \varepsilon_s E(P^s) = \mu \qquad (8^{**})$$

Also, two new variables τ and Ω were used to simplify the notation as follows:

$$\tau = \;(\, \eta^{sf}\; \alpha^{sf} - \;(1-\Phi)\, \eta^{f}\;\; \alpha^{f}\;\;)$$

$$\Omega = \;\Phi\, \Psi \;\; + (1-\Phi)\, \boldsymbol{\Gamma}$$

After these reductions, the 8x8 system reduces into:

$$\begin{bmatrix} \tau & 1 \\ -\varepsilon_S & 1 \end{bmatrix} \qquad \begin{bmatrix} \mathrm{E}(P_S) \\ \mathrm{E}(Q_S) \end{bmatrix} \qquad = \begin{bmatrix} \Omega \\ \mu \end{bmatrix}$$

Using Cramer's rule, we derive the final equations:

$$E(P^s) = \frac{(\Omega - \mu)}{(\tau + \varepsilon_s)} \qquad (9^{**})$$

$$E(Q^s) = \frac{(\tau\mu + \varepsilon_s \Omega\,)}{(\tau + \varepsilon_s)} \qquad (10^{**})$$

And using (9**) and (10**), we can derive all of the equations in the system. The producer surplus to sorghum grain producers in Nicaragua and El Salvador is given by,

$$\Delta PS_i^s = P^s * Q^s * \; E(P^s)\; (1 + 0.5E(Q^s))$$

3.2 Description of Variables

The list of the variables used for estimating the returns to R&D in Nicaragua and El Salvador and their descriptions are as follows:

Farm price of sorghum grain (Ps)	Average price ($/qq) paid to sorghum grain farmers in Nicaragua and El Salvador from the production cycle 2005/2006 to 2011/2012.
Total quantity of sorghum (Qs)	Five years average of the aggregate amount of sorghum output produced in each country measured in quintals per manzana.
Price elasticity of sorghum supply (ε_s)	Percentage change in the total quantity sorghum grain produced in Nicaragua and El Salvador, when sorghum grain price increases 1 percent.
Price elasticity of feed demand (η^{sf})	Percentage change in quantity of feed demanded in Nicaragua and El Salvador, when the price of feed increases 1 percent.
Price elasticity of sorghum flour demand (η^{f})	Percentage change in quantity of sorghum flour demanded in Nicaragua and El Salvador, when the price of sorghum flour increases 1 percent.
Cost share of sorghum grain in feed (α^{f})	Proportion of the total variable cost of producing 1 quintal of feed attributable to sorghum grain.
Cost share of sorghum grain in sorghum flour (α^{sf})	Proportion of the total variable cost of producing 1 quintal of sorghum flour attributable to sorghum grain.
Supply shifter (μ)	Shift in the Nicaraguan and Salvadorian sorghum supply curve, due to the release of new varieties, incremental number of farmers, and rise in the price of inputs.
Demand for feed shifter ($\boldsymbol{\Gamma}$)	Percent by which the feed demand curve shifts because of changes in US corn prices.

Demand for sorghum flour shifter (Ψ)	Percent by which the sorghum flour demand curve shifts because of changes in the wheat flour price.
Share of sorghum used in sorghum flour (Φ)	Proportion of the total quantity of sorghum produced in Nicaragua and El Salvador used in sorghum flour supply.

3.3 Data collection

I travelled to Nicaragua and El Salvador to collect primary information about the uses of sorghum in Central America. Professor Joe Hancock, from the Department of Animal Science at Kansas State University and INTSORMIL principal investigator for West Africa and Central America, provided the contact information about the project partners in the region. We formed an interdisciplinary research team to develop a mutual beneficial strategy used on this field trip.

A value chain approach was used to conduct the research as per the project proposal. The two main sorghum uses identified in Nicaragua and El Salvador were poultry feed and sorghum flour. We prepared a work plan to interview the actors of the production, processor, and market chain for each product in each country in July 2011. In Nicaragua, we conducted 12 interviews of members of the government, three feed companies (Cargill, Avicola La Barranca and MONISA), two non-governmental organizations, a sorghum producer association (ANPROSOR), the poultry producer association (ANAPA), and the leader of the sorghum flour research for that country. In El Salvador we conducted 9 interviews, among them the poultry producer association (AVES), the bakery producer association (MENAPAES), dairy and swine producer associations, the leaders of the sorghum flour research, representative of the agricultural board (BOLPROES), and an economist from the Salvadorian Foundation for Development (FUSADES) This approach helped us to prepare the agenda and possible questions for the interviews because very little reliable information about sorghum uses was published for these countries. Previous studies have focused on specific topics such as plant breeding, sorghum flour and sorghum for poultry feed; however, none of them has developed the economic link among these sectors

Although we are economists and not journalists, and we believe in the importance of economic models and quantitative analysis, we also realize that an economic model is a representation of the real world. Therefore, we need to know what is happening in that world to be able to simulate that reality and to influence policy. These interviews are the tool that we used as a baseline and control to understand all the different perspectives of the story behind our research.

3.4 Data sources and values calculations

The farm prices of sorghum grain in Nicaragua were provided by Mario Rosales, General Manager of Avícola La Barranca, and Francisco Vargas, Technical Secretary of ANPROSOR; the prices in El Salvador were provided by BOLPROES. Table 3.1 shows the prices paid to sorghum grain producers in Nicaragua and El Salvador.

Table 3.1 Sorghum grain prices in Nicaragua and El Salvador from 2005-2012 ($/qq)

Year	Nicaragua	El Salvador
2005-2006	8.50	7.98
2006-2007	8.50	7.94
2007-2008	10.60	10.00
2008-2009	14.50	13.25
2009-2010	10.00	12.25
2010-2011	11.50	12.25
2011-2012	14.00	15.00
Average price	11.09	11.24
Standard Deviation	2.42	2.69

The total quantity of sorghum grain was estimated based on the average total sorghum grain production of each country. Additionally, we estimated the quantity sold in the market and the proportion of production that has subsistence uses. In Nicaragua, an average of 20 percent of total production is used for subsistence purposes (seed, animal, or/and human consumption). Therefore, the remaining 80 percent is commercialized. These values were estimated based on information obtained from the interview with Francisco Vargas, ANPROSOR, and from the Nicaraguan Agriculture Ministry website. Moreover, El Salvador's, Agricultural Statistics Division affirmed that 70% of the total production is sold. Next, Table 3.2 presents the total sorghum grain production quantities in Nicaragua and El Salvador. Note that the values used in our model are the total quantities that producers sell in the market, calculated using the average quantity of the production cycle from 2005/2006 to 2011/2012 times the average percent sold, which is 80% for Nicaragua and 70% for El Salvador.

Table 3.2 Total sorghum production in Nicaragua and El Salvador from 2005-2012 (qq)

Year	Nicaragua	El Salvador
2005-2006	2,009,575	2,873,533
2006-2007	1,609,383	1,895,019
2007-2008	2,367,738	2,840,635
2008-2009	1,641,726	2,958,065
2009-2010	1,364,682	3,601,359
2010-2011	2,489,500	2,343,645
2011-2012	2,750,000	2,752,000
Quantity sold	1,626,583	1,926,425
Standard Deviation	518,696.25	530,356.82

Due to the similarities within the regions, we used the elasticity of supply and feed demand estimated for Mexico by the Food and Agricultural Policy Research Institute. First, the elasticity of sorghum supply is positive because if the price paid to producers increases, they will be willing to produce more. However, producers have resource limitations; thus, sorghum supply tends to be inelastic in the short run (Pyndyck and Rubinfeld 2005). Second, the elasticity of feed demand is negative because as price increases, quantity demanded should decrease. The percentage decline in this variable is less than the percentage increase in price; as a result, the feed demand is price inelastic (Pyndyck and Rubinfeld 2005). Finally, the sorghum flour elasticity was estimated based on economic theory assuming that since this is a new product that can be easily substituted for wheat flour, as the price increases, consumers will buy less of it. Therefore, this value is negative and elastic because the percentage change in sorghum flour quantity demanded is greater than its change in price. Table 3.4 presents the elasticities used in the model.

Table 3.3 Value of different elasticities used in the model

Type of price elasticities	Value
Sorghum Supply	0.2
Sorghum feed demand	-0.44
Sorghum flour demand	-2

The cost share of sorghum grain in feed was calculated using the average cost shares provided by Cargill and MONISA in Nicaragua, and by AVES in El Salvador. We used 15 percent for Nicaragua and 20 percent for El Salvador. The cost share of sorghum grain in sorghum flour was estimated with the information from the group, "Avanzando en mi comunidad" provided by Eliette Palacios from INTA in Nicaragua. For El Salvador, we estimated the value with information provided by Kris Duville from CENTA. Table 3.5 shows the cost shares calculated for Nicaragua and El Salvador.

Table 3.4. Cost shares of sorghum grain in feed sorghum flour in Nicaragua and El Salvador

Country	Feed cost share	Sorghum flour
Nicaragua	15%	90%
El Salvador	20%	76%

The supply and demand shift percentages are guesses based on our own comprehension of theory and the current sorghum situation in Nicaragua and El Salvador. For example, we know that the supply curve might shift if INTSORMIL releases new sorghum varieties that increase productivity. However, promoting this new technology among farmers requires time; thus, the shift in the sorghum grain supply should be no more than 5%. Moreover, the feed industry in Nicaragua and El Salvador is well established, so if the US corn price increases, feed companies will be willing to buy more sorghum grain to use in their diets. In this case, the percentage shifts used were 5, 10, and 20 percent. Although we include a 20 percent shift, we think that in the short run the shift should be between 5 and 10 percent. Lastly, the demand for sorghum flour shifts due to the change in price of wheat flour. Therefore, if the cost of wheat flour increases, small bakeries in Nicaragua and El Salvador will be more willing to use sorghum flour to reduce their productions costs, but in order to produce sorghum flour, bakeries need to have a specific type of mill. This technology requires a monetary investment that could be hard to afford. Table 3.6 presents the different percentage shifts discussed above.

Table 3.5 Percentage shifts of different market curves

Type of curve	Percentage shift
Sorghum grain supply curve	1% and 2.5%
Sorghum flour demand curve	0.5% and 1%
Feed demand curve	5%, 10% and 20%

Table 3.6 Summary of the data used for Nicaragua and El Salvador

Variable	Name	Value	Units	Source
ε_S	Elasticity of sorghum supply	0.2	N/A	Food and Agricultural Policy Research Institute (FAPRI)
η_{S0}	Elasticity demand of feed	-0.44	N/A	Food and Agricultural Policy Research Institute (FAPRI)
η_{S1}	Elasticity of demand of sorghum flour	-2	N/A	Researchers
J	Demand feed shifter	5,10,20	%	Researchers
Ψ	Demand sorghun flour shifter	1, 5		Researchers
μ	Supply shifter	1, 2.5		Researchers
Φ	Share of sorghum used in Sorghum flour	1	%	Researchers

Table 3.7 Summary of the data used for Nicaragua

Variable	Name	Value	Units	Source
Ps	Farm price of sorghum grain	$11.08	$/qq	National Sorghum Producer Association Avicola La Barranca
Qs	Total quantity of sorghum	1,626,583	qq	Forestry and Agriculture Ministry-National Sorghum Producer Association
$\alpha S0$	Cost share of sorghum grain in feed	15	%	Molinos de Nicaragua S. A.
$\alpha S1$	Cost share of sorghum grain in sorghum flour	90	%	Sauce producer cooperative

Table 3.8Summary of the data used for El Salvador

Variable	Name	Value	Units	Source
Ps	Farm price of sorghum grain	$11.24	dollars per quintals	National Sorghum Producer Association/ Avicola La Barranca
Qs	Total quantity of sorghum	1,926,426	quintals	Forestry and Agriculture Ministry/ National Sorghum Producer Association
$\alpha S0$	Cost share of sorghum grain in feed	20	%	Molinos de Nicaragua S. A.
$\alpha S1$	Cost share of sorghum grain in sorghum flour	76	%	Sauce producer cooperative

Chapter 4 - Estimation of the Returns to R&D from Sorghum Value Added products

The objective of this chapter is to estimate the percentage changes in price and quantities of sorghum grain and sorghum value added product as well as to estimate the benefit that producers in Nicaragua and El Salvador will gain if the demand curve of feed concentrate and sorghum flour shifts.

To test a variety of potential market outcomes, we simulated 8 different scenarios using our equilibrium displacement model for Nicaragua and El Salvador. In scenario I, we shifted the sorghum supply curve for both countries 1 percent and 2.5 percent while the sorghum flour and feed curve did not shift. Scenario II presents a 1 percent and 5 percent shift in the sorghum flour demand curve without shifting the other two curves. In scenario III, we simulated a 5, 10, and 20 percent shift in the feed demand curve. Scenario IV shows 0.5, 1, and 5 percent changes in the sorghum supply curve, while the sorghum flour demand shifts 1 and 5 percent, respectively. Scenario V represents 1.1, 5, and 10 percent shifts in the feed demand curve, while the sorghum supply curve shifts by 1 and 2.5 percent. In scenario VI, we simulated shifts in the three curves: 1.5, 5, and 20 percent in the feed demand curve, 1, 5, and 5 percent in the sorghum flour curve, and 1, 1, and 2.5 percent in the sorghum supply curve, respectively. In the last two scenarios, we simulated the shifts based on producer surplus, so in scenario VII, we compared the results obtained when the feed demand curve changes by 1 percent with the shift in sorghum flour curve by 90 percent. Finally, in scenario VIII, we added the shift in the sorghum supply curve by 1 and 2.5 percent, when the sorghum flour curve shifts 90 percent and the feed demand curve shifts by 1 percent. Table 5.1 presents the summary of the 8 scenarios simulated in this research with the demand or supply shifts presented in parentheses.

Table 4.1Summary of the scenarios used in the equilibrium displacement model

Scenarios	Supply shifter	Sorghum flour demand shifter	Feed demand shifter
I	Yes (1%, 2.5%)	No	No
II	No	Yes (1%, 5%)	No
III	No	No	Yes (5%, 10%, 20%)
IV	Yes (1%, 0.5% 5%)	Yes (1%, 5%, 5%)	No
V	Yes (1%, 5%)	No	Yes (1%, 5%)
VI	Yes (1%, 1%, 5%)	Yes (1% / 5%/ 5%)	Yes (1.5%, 5%, 10%)
VII	No	Yes (90%)	Yes (1%)
VIII	Yes (0%, 1%,2.5%)	Yes (90%)	Yes (1%)

4.1 Scenario I: Shift in sorghum supply curves in Nicaragua and El Salvador

We analyzed the results of shifting just the supply curve by 1% and 2.5 % in Nicaragua as Table 4.2 shows. The farm price paid to producers decreases 3 percent, and the total quantity of sorghum increases 0.3 percen;t under a 1% supply shift the price of sorghum flour decreases 3 percent, but the quantity of sorghum used in sorghum flour increases by 6 percent. The price of feed will decrease by 0.6%, while the quantity used in feed production will increase by 0.25%. Under a 2.5 % supply shift the farm price of sorghum grain decreases 8.5% while the quantity of sorghum increases by 0.8%. The price of sorghum flour decreases by 8 percent, but the quantity of sorghum used in sorghum flour increases 15%. The price of feed decreases 1.4 percent and the sorghum used in sorghum feed increases 0.6%. When the sorghum supply curve shifts without the demand curve shifting, Nicaraguan sorghum producers lose between $600,000 and $ 1.5 million.

Table 4.2 Changes in supply shifter in Nicaragua

Percent shift in Nicaragua sorghum grain supply	1%	2.5%
Percentage change in price of sorghum flour	-3.08%	-7.70%
Percentage change in price of feed	-0.58%	-1.45%
Percentage change in quantity of sorghum used in sorghum flour	6.16%	15.41%
Percentage change in quantity of sorghum used in feed	0.25%	0.64%
Percentage change in farm price of sorghum grain	-3.42%	-8.56%
Percentage change in total quantity of sorghum	0.31%	0.79%
Producer surplus ($)	(618,631)	(1,550,227)

Table 4.3 presents the results of shifting the sorghum supply curve by 1 and 2.5 percent in El Salvador. When just the supply curve shifts by 1%, the farm price of sorghum decreases 3 %, and the quantity of sorghum increases 0.3%. The price of sorghum flour decreases 2.7 percent while the quantity of sorghum used in sorghum flour increases by 5.4%. The price of feed decreases 0.7% and the quantity of sorghum used in feed decreases 0.29%. Next, we developed the analysis using the 2.5 percent shift. Thus, the farm price that producers are paid decreases by 8% and the total quantity increases 0.8 percent; meanwhile, the price of sorghum flour decreases 7 percent while the quantity used in sorghum flour increases 14 percent. Moreover, the feed price decreases 2 percent and the quantity of sorghum used in feed increases 0.7 percent. In this scenario, Salvadorian producers lose approximately $700,000 to 1.8 million.

The results presented in tables 4.2 and 4.3 indicate that Nicaraguan and Salvadorian sorghum grain producers will not benefit if INTSORMIL focuses its resources only on developing new varieties of sorghum seed to increase productivity. However, small bakeries and feed producers will gain because their raw material (sorghum grain) has a lower cost; therefore, their cost of production will decrease and their profit margin will increase.

Table 4.3 Changes in supply shifter in El Salvador

Percent shift in El Salvador sorghum grain supply	1%	2.50%
Percentage change in price of sorghum flour	-2.70%	-6.76%
Percentage change in price of feed	-0.67%	-1.69%
Percentage change in quantity of sorghum used in sorghum flour	5.41%	13.53%
Percentage change in quantity of sorghum used in feed	0.29%	0.74%
Percentage change in farm price of sorghum grain	-3.38%	-8.45%
Percentage change in total quantity of sorghum	0.32%	0.80%
Producer surplus ($)	(733,795)	(1,838,928)

4.2 Scenario II: Shift in sorghum flour demand curves in Nicaragua and El Salvador

Table 4.4 presents the results of shifting the Nicaraguan sorghum flour demand curve by 1 and 5 percent. For example, a 1 percent shift in the demand curve generates a little benefit for sorghum grain producers. However, the percentage changes in prices and quantities will not be affected by more than 1 percent.

Table 4.4 Changes in sorghum flour demand shifter in Nicaragua

Percent shift in Nicaragua sorghum flour demand	1%	5%
Percentage change in price of sorghum flour	0.03%	0.15%
Percentage change in price of feed	0.00%	0.02%
Percentage change in quantity of sorghum used in sorghum flour	0.93%	4.69%
Percentage change in quantity of sorghum used in feed	-0.00%	-0.01%
Percentage change in farm price of sorghum grain	0.03%	0.17%
Percentage change in total quantity of sorghum	0.00%	0.03%
Producer surplus ($)	6,177	30,888

Moreover, a 5 percent shift increases the farm price by 0.1 percent while the quantity of sorghum used in sorghum flour increases 5 percent.

Table 4.5 presents the shifts in sorghum flour demand for El Salvador. Notably, Salvadorian sorghum producers receive 60 percent less benefit than Nicaraguan sorghum producers when the demand curve is shifted 5 percent.

Table 4.5 Changes in sorghum flour demand shifter in El Salvador

Percent shift in El Salvador sorghum flour demand	1%	5%
Percentage change in price of sorghum flour	0.01%	0.07%
Percentage change in price of feed	0.00%	0.02%
Percentage change in quantity of sorghum used in sorghum flour	0.97%	4.87%
Percentage change in quantity of sorghum used in feed	-0.00%	-0.01%
Percentage change in farm price of sorghum grain	0.02%	0.08%
Percentage change in total quantity of sorghum	0.00%	0.02%
Producer surplus ($)	3,663	18,317

Overall, sorghum grain producers in Nicaragua and El Salvador would gain benefit if INTSORMIL were to promote the demand of sorghum flour as a substitute for wheat flour, without generating new technology. The benefit presented in tables 4.4 and 4.5 seems small; however, this gain is relative to the GDP per capita of each country.

4.3 Scenario III: Shift in feed demand curve in Nicaragua and El Salvador

Using the Nicaragua data, we simulate a feed demand curve shift of 5, 10, and 20 percent. With a 5 percent shift, the farm price of sorghum grain increases 17 percent and the quantity of sorghum increases 3 percent. Also, the price of sorghum flour increases 15 percent while the quantity of sorghum used in sorghum flour decreases 30%. Moreover, the price of feed increases 2 percent and the quantity of sorghum used in feed increases 4 percent. Accordingly, sorghum producers gain over 3 million dollars with this shift. Table 4.6 shows the results of the shifts in the feed demand curve.

Table 4.6 Changes in feed demand shifter in Nicaragua

Percent shift in Nicaragua feed demand	5%	10%	20%
Percentage change in price of sorghum flour	15.25%	30.51%	61.02%
Percentage change in price of feed	2.88%	5.76%	11.53%
Percentage change in quantity of sorghum used in sorghum flour	-30.50%	-61.02%	-122.03%
Percentage change in quantity of sorghum used in feed	3.73%	7.46%	14.93%
Percentage change in farm price of sorghum grain	16.95%	33.90%	67.80%
Percentage change in total quantity of sorghum	3.40%	6.78%	13.56%
Producer surplus ($)	3,109,224	6,322,088	13,058,737

Table 4.7 presents the results of shifting the feed demand curve 5, 10, and 20 percent. In particular, the farm price of sorghum grain increases 34 percent when the demand curve shifts 10 percent. Also, the quantity of sorghum increases 7 percent. The price of sorghum flour increases 30 percent, but the quantity of sorghum used in sorghum flour decreases 61 percent. Meanwhile, the price of feed increases 6 percent and the quantity of sorghum used in feed increases 7 percent.

Table 4.7 Changes in feed demand shifter in El Salvador

Percent shift in El Salvador feed demand	5%	10%	20%
Percentage change in price of sorghum flour	13.46%	26.93%	53.86%
Percentage change in price of feed	3.36%	6.73%	13.47%
Percentage change in quantity of sorghum used in sorghum flour	-26.93%	-53.86%	-107.73%
Percentage change in quantity of sorghum used in feed	3.52%	7.04%	14.07%
Percentage change in farm price of sorghum grain	16.83%	33.66%	67.33%
Percentage change in total quantity of sorghum	3.37%	6.73%	13.47%
Producer surplus ($)	3,706,086	7,534,871	15,560,541

Interestingly, sorghum producers gain higher benefit when the feed demand curve shifts than when the sorghum flour demand curve shifts. This indicates that INTSORMIL could consider investing more resources in promoting sorghum grain as a substitute for imported yellow corn. The project also can promote small households raising broilers by feeding them with sorghum grain. This would improve food security in rural areas in Nicaragua and El Salvador.

4.4 Scenario IV: Shift in sorghum flour demand curves and sorghum supply curve

For Nicaragua, the results presented in table 4.8 show that as the percentage shift in the sorghum supply curve increases, the producer surplus decreases when we shift the sorghum flour demand and the sorghum supply curve at the same time. With a 0.5 percent shift in the sorghum supply and 5 percent shift in the sorghum flour curve, the farm price of sorghum decreases 1.5 percent and the quantity of sorghum grain increases 0.2 percent. Also, the price of sorghum flour decreases 1.4 percent while the quantity of sorghum used in sorghum flour increases 8 percent. Meanwhile, the feed price decreases 0.2 percent and the quantity of sorghum used in feed increases 0.1 percent.

Table 4.8 Changes in sorghum flour demand shifter and sorghum grain supply shifter in Nicaragua

Percent shift in Nicaragua sorghum flour and sorghum grain	1%	5%/0.5%	5%/1%
Percentage change in price of sorghum flour	-3.05%	-1.38%	-2.92%
Percentage change in price of feed	-0.57%	-0.26%	-0.55%
Percentage change in quantity of sorghum used in sorghum flour	7.10%	7.77%	10.85%
Percentage change in quantity of sorghum used in feed	0.25%	0.11%	0.24%
Percentage change in farm price of sorghum grain	-3.39%	-1.54%	-3.25%
Percentage change in total quantity of sorghum	0.32%	0.19%	0.35%
Producer surplus ($)	(415,766)	(278,212.43)	(587,799.71)

Table 4.9 presents the results of this scenario for El Salvador. First, the farm price of sorghum grain decreases 3 percent while the total quantity of sorghum increases 0.3 percent when the sorghum flour curve shifts by 5 percent and sorghum flour shifts 1 percent. Also, the price of sorghum flour decreases 3 percent and the quantity of sorghum used in sorghum flour increases 10 percent. Finally, the feed price decreases 0.6 percent and the quantity of sorghum used in feed increases 0.3 percent.

Table 4.9 Changes in sorghum flour demand shifter and sorghum grain supply shifter in El Salvador

Percent shift in El Salvador sorghum flour and sorghum grain	1%	5%/0.5%	5%/1%
Percentage change in price of sorghum flour	-2.69%	-1.28%	-2.63%
Percentage change in price of feed	-0.67%	-0.32%	-0.66%
Percentage change in quantity of sorghum used in sorghum flour	6.38%	7.57%	10.27%
Percentage change in quantity of sorghum used in feed	0.29%	0.14%	0.29%
Percentage change in farm price of sorghum grain	-3.36%	-1.60%	-3.29%
Percentage change in total quantity of sorghum	0.32%	0.17%	0.34%
Producer surplus ($)	(730,138)	(348,300.56)	(715,510.09)

The results of this scenario show a more realistic pattern . As part of INTSORMIL activities, the project has been realizing new seed varieties to increase yield and has been promoting sorghum flour in Nicaragua and El Salvador. The results indicate that producers will not gain benefit if the project executes both activities simultaneously. Instead, the benefit gain by promoting sorghum flour will decrease drastically when there is more sorghum grain in the market.

4.5 Scenario V: Shift in feed and sorghum grain curves

Table 4.10 shows the results of shifting the feed demand and the sorghum grain supply curve by different percentages. We shifted the supply curve 1 percent and the feed curve 1.1 percent because this is the lowest possible percentage that the feed curve needs to shift in order for producers to gain surplus.

A shift of 5 percent in the feed curve and 1 percent in the supply curve suggests that the farm price increases 14 percent and the total quantity of sorghum increases 4 percent. Meanwhile, the feed price increases 2 percent and the quantity of sorghum used in feed increases 4 percent. This scenario indicates that Nicaraguan producers gain a benefit of 2 million dollars.

Table 4.10Changes in feed demand shifter and sorghum grain supply shifter in Nicaragua.

Percent shift in Nicaragua feed and sorghum grain	1.1%/1%	5%/1%	10%/2.5%
Percentage change in price of sorghum flour	0.27%	12.17%	22.80%
Percentage change in price of feed	0.05%	2.29%	4.30%
Percentage change in quantity of sorghum used in sorghum flour	-0.54%	-24.34%	-45.60%
Percentage change in quantity of sorghum used in feed	1.07%	3.98%	8.10%
Percentage change in farm price of sorghum grain	0.30%	13.52%	25.33%
Percentage change in total quantity of sorghum	1.06%	3.70%	7.56%
Producer surplus ($)	55,263	2,484,943	4,743,609

In El Salvador, the farm price increases 25 percent and the total quantity of sorghum increases 8 percent, when we shift the feed curve 10 percent and the supply curve 2.5 percent. Additionally, the price of sorghum flour increases 20 percent while the sorghum used in sorghum flour decreases 40 percent. Meanwhile, the feed price increases 5 percent and the quantity of sorghum used in feed increases 8 percent. Clearly, as the percentage shift in the feed curve increases, the producer surplus increases as well.

Table 4.11Changes in feed demand shifter and sorghum grain supply shifter in El Salvador

Percent shift in El Salvador feed and sorghum grain	1.1%/1%	5%/1%	10%/2.5%
Percentage change in price of sorghum flour	0.25%	10.75%	20.16%
Percentage change in price of feed	0.06%	2.69%	5.04%
Percentage change in quantity of sorghum used in sorghum flour	-0.51%	-21.51%	-40.33%
Percentage change in quantity of sorghum used in feed	1.07%	3.81%	7.78%
Percentage change in farm price of sorghum grain	0.32%	13.44%	25.20%
Percentage change in total quantity of sorghum	1.06%	3.69%	7.54%
Producer surplus ($)	69,600	2,965,851	5,663,745

The results presented in table 4.10 and 4.11 show that the impact of shifting the demand of feed will not be affected when producers increase their yields. In the case of a shift in the sorghum supply curve, the project can also release varieties with characteristics that meet the feed industry demand, and can train farmers to have better post-harvest practices. Ultimately, promoting sorghum grain as a substitute for corn can be really beneficial for sorghum producers.

4.6 Scenario VI: Shift in feed, flour, and supply

In this scenario, all three curves shifted. We shifted feed 1.5 percent, sorghum flour 1 percent, and supply 1 percent. Then, feed shifted 5 percent, sorghum flour 5 percent, and supply 1 percent. Finally, feed shifted by 20 percent, flour by 5 percent, and supply by 2.5 percent. Our results show that ideally, the best simulation is one in which the industry increases 1.5 percent, sorghum flour increases 1 percent, and sorghum grain increases 1 percent such that percentage changes in prices are not more than 1%, which represents a benefit for all the sectors.

In Nicaragua, the farm price increases 2 percent and the total quantity of sorghum increases 1 percent while the price of sorghum flour increases 1.5 percent, but the quantity of sorghum used in sorghum flour decreases 2 percent. Also, the price of feed increases 0.3 percent and the quantity of sorghum used in feed increases 1 percent. Then, resulting surplus indicates that sorghum producers gain a benefit of 300 thousand dollars.

Table 4.12 Changes in feed, flour demand shifter, and sorghum grain supply shifter in Nicaragua

Percent shift in Nicaragua feed, flour and sorghum grain	1.5%/1%/1%	5%/5%1%	20%/5%/2.5%
Percentage change in price of sorghum flour	1.52%	12.32%	53.46%
Percentage change in price of feed	0.28%	2.32%	10.09%
Percentage change in quantity of sorghum used in sorghum flour	-2.05%	-19.65%	-101.93%
Percentage change in quantity of sorghum used in feed	1.37%	3.97%	15.55%
Percentage change in farm price of sorghum grain	1.69%	13.69%	59.40%
Percentage change in total quantity of sorghum	1.33%	3.73%	14.38%
Producer surplus ($)	307,787	2,516,821	11,486,939

Table 4.13 shows Salvadorian producers gain approximately 3 million dollars when the feed and flour demand curve shifts 5 percent and the sorghum supply curve shifts 1 percent. Also, the farm price of sorghum increases 13 percent and the total quantity increases 4 percent. Meanwhile, the price of sorghum flour increases 11 percent and the quantity of sorghum used in flour decreases 17 percent. Also, the price of feed increases 3 percent while the quantity of sorghum used in feed increases 4 percent.

Table 4.13 Changes in feed, flour demand shifter and sorghum grain supply shifter in El Salvador

Percent shift in El Salvador feed, flour and sorghum grain	1.5%/1%/1%	5%/5%1%	20%/5%/2.5%
Percentage change in price of sorghum flour	1.34%	10.82%	47.16%
Percentage change in price of feed	0.33%	2.70%	11.79%
Percentage change in quantity of sorghum used in sorghum flour	-1.69%	-16.65%	-89.32%
Percentage change in quantity of sorghum used in feed	1.35%	3.80%	14.81%
Percentage change in farm price of sorghum grain	1.68%	13.53%	58.95%
Percentage change in total quantity of sorghum	1.33%	3.70%	14.29%
Producer surplus ($)	366,909	2,984,753	13,677,919

According to INTSORMIL current strategy and activities in Nicaragua and El Salvador, this scenario presents the most accurate reproducible results. Clearly, producers gain benefit when the project generates new technology to promote sorghum flour, but also promotes the utilization of sorghum in the feed industry.

4.7 Scenario VII: Shift in feed and sorghum flour demand giving a similar result to that for producer surplus.

Scenarios I to VI present various simulations in which both demand curves shifted, and the results showed that feed had more impact on producer surplus than did sorghum flour; however, the results didn't indicate by how much. Tables 4.14 shows that shifting the feed curve 1 percent generates a gain of approximately $600,000 for Nicaraguan producers, and in order to get a similar surplus, the sorghum flour demand needs to shift 90 percent.

Table 4.14 Producer surplus increasing demand curve of feed and sorghum flour in Nicaragua

Percent shift in Nicaragua demand curves	Feed 1%	Flour 90%
Percentage change in price of sorghum flour	3.05%	2.77%
Percentage change in price of feed	0.57%	0.52%
Percentage change in quantity of sorghum used in sorghum flour	-6.10%	84.45%
Percentage change in quantity of sorghum used in feed	0.74%	-0.23%
Percentage change in farm price of sorghum grain	3.39%	3.08%
Percentage change in total quantity of sorghum	0.67%	0.61%
Producer surplus ($)	613,554	557,605

Moreover, table 4.15 shows that Salvadorian producers gain approximately $700,000 when the feed demand curve shifts 1 percent, and in order to get similar surplus, the sorghum flour demand curve needs to shift over 90 percent.

Unfortunately, this scenario is unrealistic because a 90 percent shift in the sorghum flour curve means that this product will have become an industrial product and replaced wheat flour. However, to produce sorghum flour requires new technology, and this requires time and investment.

Table 4.15 Producer surplus increasing demand curve of feed and sorghum flour in El Salvador

Percent shift in El Salvador demand curves	Feed 1%	Flour 90%
Percentage change in price of sorghum flour	2.69%	1.21%
Percentage change in price of feed	0.67%	0.30%
Percentage change in quantity of sorghum used in sorghum flour	-5.38%	87.56%
Percentage change in quantity of sorghum used in feed	0.70%	-0.13%
Percentage change in farm price of sorghum grain	3.36%	1.52%
Percentage change in total quantity of sorghum	0.67%	0.30%
Producer surplus ($)	731,401	330,177

4.8 Scenario VIII: Shift in all three curves

In this scenario, the sorghum flour demand curve is shifted 90 percent while the feed curve is shifted 1 percent, and the sorghum supply curve shifts 0, 1 and 2.5 percent. Tables 4.16 and 4.17 show that as we increase the percentage change in the sorghum supply curve, Nicaraguan and Salvadorian producers lose benefit. Furthermore, the farm price of sorghum grain decreases when the shift in sorghum supply curve is bigger than the shift in the feed curve.

Table 4.16 Changes in flour, feed and sorghum supply shifter in Nicaragua

Percent shift in Nicaragua flour, feed and sorghum grain	90%/1%	90%/1%/1%	90%/1%/2.5%
Percentage change in price of sorghum flour	5.82%	2.74%	-1.88%
Percentage change in price of feed	1.10%	0.51%	-0.35%
Percentage change in quantity of sorghum used in sorghum flour	78.35%	84.51%	93.76%
Percentage change in quantity of sorghum used in feed	0.51%	0.77%	1.15%
Percentage change in farm price of sorghum grain	6.47%	3.04%	-2.08%
Percentage change in total quantity of sorghum	1.29%	1.60%	2.08%
Producer surplus ($)	1,174,927	554,139	(380,694)

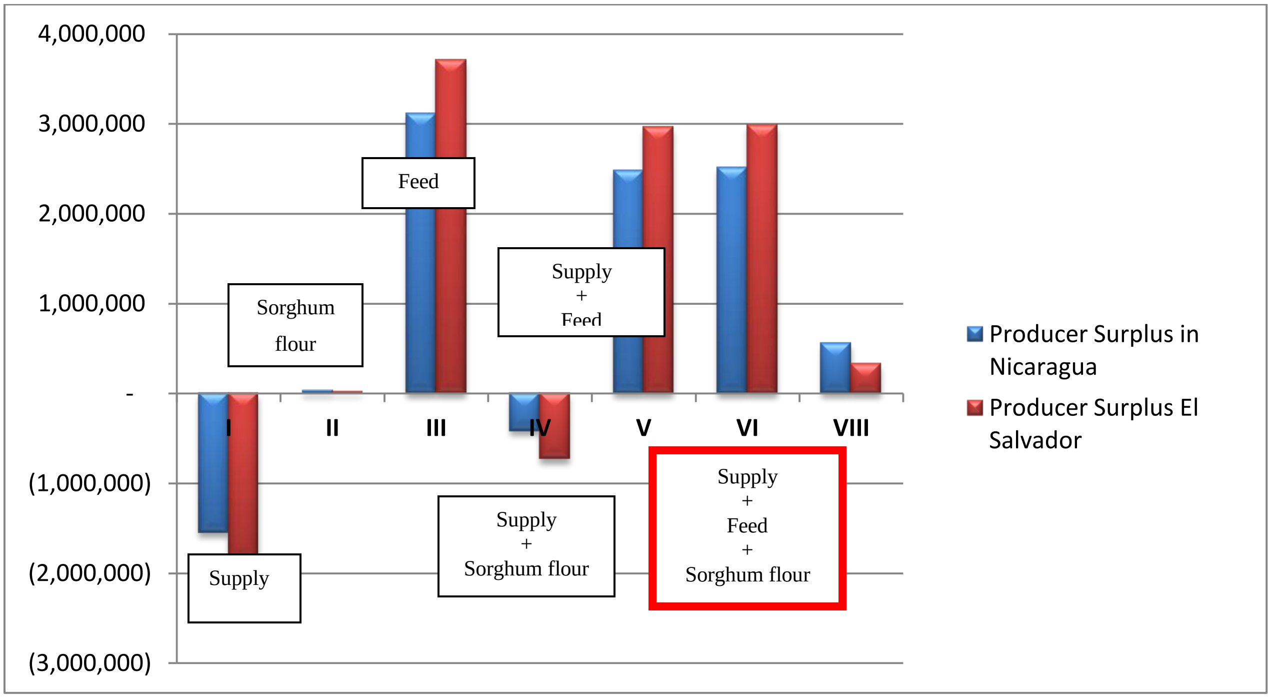
Table 4.17Change in flour, feed and sorghum supply shifter in El Salvador

Percent shift in El Salvador flour, feed and sorghum grain	90%/1%	90%/1%/1%	90%/1%/2.5%
Percentage change in price of sorghum flour	3.91%	1.20%	-2.85%
Percentage change in price of feed	0.97%	0.30%	-0.71%
Percentage change in quantity of sorghum used in sorghum flour	82.17%	87.59%	95.71%
Percentage change in quantity of sorghum used in feed	0.57%	0.86%	1.31%
Percentage change in farm price of sorghum grain	4.88%	1.50%	-3.56%
Percentage change in total quantity of sorghum	0.97%	1.30%	1.78%
Producer surplus ($)	1,063,797	328,132	(779,806)

4.9 Summary of the Results and Their Policy Implications

Figure 4.9 shows the surplus that Nicaraguan and Salvadorian producers gain or lose if any of the scenarios simulated occurs. In scenario I, producers will not gain surplus if the project just focuses on developing new technology to increase yield. In scenario II, producers gain a small proportion of benefit if the project promotes sorghum flour without developing new technology. In scenario III, producers significantly increase their benefit when the project focuses its effort on promoting sorghum grain as a substitute for corn without developing new technology. In scenario IV, sorghum producers do not gain benefit when INTSORMIL focuses its activity on developing new varieties and promoting sorghum flour. In scenario V, producers gain a lot of benefit when promoting the consumption of sorghum grain for feed industry is one activity of the project. In scenario VI, sorghum producers gain a significant benefit when INTSORMIL develops three activities: 1) Developing new technology; 2) Promoting sorghum flour; 3) Promoting feed concentrate. In scenario VIII, producers gain benefit when the project promotes sorghum flour as the main activity, but also allocates some resources to develop new technology and promote sorghum for feed concentrate.

Figure 4.1Nicaragua and El Salvador producer surplus of the different scenarios simulated with the equilibrium displacement model



Clearly, the value added product that generates more benefit for sorghum producers in Nicaragua and El Salvador is feed concentrate. Furthermore, this product is part of a well-established industry in both countries, which makes it easier to develop activities that increase the quantity of sorghum that feed companies buy. However, it is necessary to design a strategy for each country: 1) In Nicaragua, companies are willing to buy more sorghum, but there is not enough supply. INTSORMIL can work with varieties that they have already developed and provide technical support through the INTA to small and medium farmers. Also, the project can train sorghum producers to be aware of the chemical and physical characteristics of their product. This same training can be given to feed companies. Part of this strategy can be to promote a family production program in which women feed the chickens with the sorghum that is grown in small plots in their garden. 2) In El Salvador, AVES is the poultry association that regulates the quantity of grain that companies buy. Therefore, INTSORMIL needs to work closely with this organization in order to increase the consumption of sorghum grain for feed concentrate.

Moreover, sorghum flour does not generate a lot of direct benefit for sorghum producers; however, it does for bakers and the people in those countries. Therefore, when the price of wheat flour is high because of international prices and oligopsony, sorghum flour is a feasible alternative for poor families with low income. In both countries, INTOSORMIL needs to promote an effective sorghum flour production system; they can do this by helping bakeries to associate and by creating partnerships with other organizations to help with the purchase of the requisite mill.

Chapter 5 - Conclusions

The objective of this study was to estimate the percentage changes in quantities and prices of sorghum and its value added products in Nicaragua and El Salvador by using an equilibrium displacement model. The information drawn from interviews with 21 actors in the sorghum supply chain in those countries formed the baseline and control by which to analyze the results of this research. Nicaragua and El Salvador sorghum production is regulated by an agreement among the government, producers and feed industry. However, the agreement fixes a low price for sorghum grain that usually does not cover the farmer's production costs. Companies argue that sorghum has less nutritional value than maize. As a consequence of the low price, producers decrease their production because of lower incentive.

Following Balagtas et al. an equilibrium displacement model was used to simulate 8 different potential market outcomes. The results showed that if INTSORMIL just developed new seeds to increase yield, producers could decrease lost money. However, if the project enhances the marketing of sorghum flour and feed concentrate, the producers will benefit. In Scenario VI the three curves were shifting, showing that producers get the most benefit when they have access to new technology but at the same time, they have a market demand for sorghum grain.

The impact of sorghum flour is low compared to that of feed concentrate because of the structure of the feed industry. However, sorghum flour still generates benefit to sorghum flour producers and to small bakeries that cannot afford the price of wheat flour. However, feed as concentrate is the sorghum value added product that can benefit producers the most.

This research suggests that INTSORMIL develops a new strategy for the Central America countries to increase the resources to promote sorghum as a substitute for maize in the feed industry. Additionally, it is necessary that the project generates hands-on small training projects for women from rural areas in order to teach them how to grow sorghum and feed the grain the garden chickens. This strategy will increase income and improve food security. Another action that is necessary is to work with the association of small bakeries to facilitate the sorghum flour process, so the bakeries can access group mills, and the cost of the flour will be less than that of wheat flour. INTSORMIL in Nicaragua and El Salvador needs to develop partnerships with other local NGO's such as World Vision, CARE, SNV, AECID, Swisscontact, the European Commission, and FUSADES. Through such partnerships, the project can promote sorghum flour and feed in rural areas where food security is an issue. This is because sorghum grain producers need training to improve their knowledge about the characteristics of the grain in order to negotiate a better price.

Recommendations

INTSORMIL should participate in the yearly agreement in which the sorghum price is set. In fact, this study can be used as a tool to suggest by how much the price should increase or decrease. Next, the project should develop a value chain study of sorghum and it needs to be specific by country. We also recommend that the project develop a database of all the organizations that are working with sorghum to prepare a revision of all the available documentation regarding sorghum grain production and its value added products. This information is necessary to influence policy at governmental level.

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