

An Economic Surplus Evaluation of Aflatoxin-Reducing Research: A Case Study of Senegal's Confectionery Groundnut Sector

Louis Boakye-Yiadom

Thesis submitted to the Faculty of
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Master of Science
in
Agricultural and Applied Economics

Committee:

Dr. George Norton (Chair)

Dr. Bradford Mills

Dr. Charlene Brewster

January 9, 2003

Blacksburg, Virginia

Keywords: Aflatoxin; Confectionery groundnuts; Senegal; Economic surplus; Research

Copyright 2003, Louis Boakye-Yiadom

An Economic Surplus Evaluation of Aflatoxin-Reducing Research: A Case Study of Senegal's Confectionery Groundnut Sector

Louis Boakye-Yiadom

(Abstract)

In international trade involving agricultural products, attempts to safeguard the health of humans, animals, and plants, have led to the imposition of sanitary and phytosanitary (SPS) standards. Due to the fact that groundnuts are susceptible to aflatoxin contamination, stringent aflatoxin standards have been imposed on groundnut trade by many developed countries. For Senegal and other groundnut exporters in the developing world, these aflatoxin standards pose a major challenge. As a result, in Senegal's confectionery groundnut sector, CIRAD (a French scientific organization) has commenced research aimed at developing an aflatoxin-reducing program. This study evaluates the potential economic impact of CIRAD's aflatoxin-reducing program.

The hypotheses underlying the study are as follows:

- (i) The adoption of CIRAD's aflatoxin-reducing program would enhance the welfare of Senegal's confectionery groundnut farmers.
- (ii) An overall welfare net-gain would be derived by Senegal from the adoption of the program.

The analysis employs an economic surplus model that incorporates trade, as well as, domestic production and consumption. Various scenarios of program-effectiveness are examined. The results support the hypotheses of the study; besides enhancing farmers' welfare, the adoption of the aflatoxin-reducing program is expected to yield an overall net-gain ranging between US\$0.56 million and US\$4.25 million. The overall net-gain is, however, very small.

Dedication

To my wife, Serwaa, and my son, Adom. Their unflinching support is ample evidence of God's faithfulness to me.

Acknowledgements

Throughout the various stages of this thesis, I was blessed to benefit from the support of several individuals and institutions. It is therefore fitting that I acknowledge my indebtedness to these.

My heartfelt gratitude goes to my committee chair, Dr. George Norton for his meticulous and competent supervision of the work. Drs. Bradford Mills and Charlene Brewster — the other committee members — were also of immense assistance. The support provided by my committee extended beyond highly useful comments and suggestions, to the provision of data, books, and literature. I am also thankful to Dr. David Orden for generously providing me with highly valuable literature. The information provided (through correspondence) by Dr. Laurent Sagarra is also highly appreciated.

The financial support provided by the U.S. Agency for International Development (USAID) through the Peanut CRSP (Grant Number: AG-G-00-96-900013-00) administered at Virginia Tech through the Office of International Research, Education, and Development (OIREED) is gratefully acknowledged. I am also thankful to Virginia Tech's Department of Agricultural and Applied Economics for the institutional support provided.

Table of Contents

Abstract	ii
Dedication	iii
Acknowledgements	iv
List of Figures	viii
List of Tables	ix
Glossary	x
Chapter One: Introduction	1
1.1 Introduction	1
1.2 Problem Statement	2
1.3 Objectives	5
1.4 Hypotheses	6
1.5 Methods	6
1.6 Organization	6
Chapter Two: An Overview of Senegal’s Groundnut Sector	7
2.1 Introduction	7
2.2 The West African Groundnut Industry	7
2.3 Senegal’s Groundnut Sector	8
2.3.1 Some Macroeconomic Developments	8
2.3.2 Groundnut Production	9
2.3.3 Marketing of Groundnuts	13
2.3.4 Groundnut Pricing	19
2.4 Groundnut Aflatoxin Research in Senegal and West Africa	21
2.4.1 Groundnut Aflatoxin Research in West Africa	21
2.4.2 Aflatoxin Research in Senegal’s Confectionery Groundnut Sector	23
2.5 Conclusion	26
Chapter Three: Methodology	27
3.1 Introduction	27
3.2 The Use of Economic Surplus Measures in Agricultural Research Evaluation	27

3.2.1 The Basic Model	27
3.2.2 Some Conceptual Issues	29
3.2.3 Some Empirical Studies	31
3.3 Technical Barriers to Trade	35
3.3.1 Implementation of Sanitary and Phytosanitary (SPS) Regulations	35
3.3.2 A Survey of Some Theoretical and Empirical Studies on Technical Barriers to Trade	37
3.4 The Empirical Model	40
3.4.1 Some Assumptions	40
3.4.2 The Market Impact of Aflatoxin-Reducing Research	44
3.4.3 The Determination of the Overall Change in Economic Surplus	45
3.5 Data Requirements and Some Derivations	47
3.5.1 Prices	47
3.5.2 Quantities	48
3.5.3 Elasticities of Demand and Supply	49
3.5.4 Program Adoption Profile	49
3.5.5 Discount Factor	51
3.5.6 Research Cost	51
3.5.7 Probability of Research Success	52
3.5.8 Derivation of Supply and Demand Functions	53
3.5.9 Computational Requirements for the “ K_t -Shift” Parameters	54
3.5.10 Program-Induced Percentage Net Quantity Gains Under Different Scenarios of Program-Effectiveness	56
Chapter Four: Results	59
4.1 Introduction	59
4.2 Presentation of Results	59
4.2.1 Scenario One: A 30% Increase in High Quality Groundnuts	59
4.2.2 Scenario Two: A 40% Increase in High Quality Groundnuts	61
4.2.3 Scenario Three: A 50% Increase in High Quality Groundnuts	62

4.2.4 Scenario Four: A 60% Increase in High Quality Groundnuts	63
4.3 Discussion of Results	64
4.4 Conclusion	66
Chapter Five: Summary and Recommendations	68
5.1 Summary	68
5.2 Results	71
5.3 Recommendations	72
5.4 Conclusion	73
References	74
Vita	80

List of Figures

Figure 2.1 Senegal's Groundnut Output	11
Figure 2.2 Senegal's Quantity of Groundnut Exports	17
Figure 2.3 Senegal's Groundnut Production and Exports of Groundnut Products	18
Figure 2.4 Senegal's Exports (Value) of Groundnut Products	18
Figure 2.5 Senegal's Groundnut Producer Price	21
Figure 3.1 The Basic Economic Surplus Model	28
Figure 3.2 The Markets for Senegal's Confectionery Groundnuts	45
Figure 3.3 The Program Adoption Profile	50

List of Tables

Table 1.1 Aflatoxin Maximum Admissible Levels	4
Table 2.1 Senegal's Groundnut Production	10
Table 2.2 Senegal's Groundnut Exports	16
Table 2.3 Share of Export Value of Groundnut Products by Destination: 1985-98	19
Table 2.4 Senegal's Groundnut Producer Price	20
Table 3.1 Scope of Measure from Importer and Exporter Perspective	38
Table 3.2 Research Cost	52
Table 3.3 Parameter Values for the Computation of Economic Surplus Changes	53
Table 3.4 Derivation of Expected Net-Revenue Gain	55
Table 3.5 Parameter Values for the Estimation of Percentage Net Quantity Gains Under Various Levels of Program-Effectiveness	57
Table 3.6 Estimated "Without-Program" and "With-Program" Costs of Production	57
Table 3.7 Percentage Net-Quantity Gains Under Different Scenarios	58
Table 4.1 Economic Surplus Changes and Overall Net-Gain for Scenario One	60
Table 4.2 Distribution of Producer Gains for Scenario One	60
Table 4.3 Economic Surplus Changes and Overall Net-Gain for Scenario Two	61
Table 4.4 Distribution of Producer Gains for Scenario Two	62
Table 4.5 Economic Surplus Changes for and Overall Net-Gain Scenario Three	62
Table 4.6 Distribution of Producer Gains for Scenario Three	63
Table 4.7 Economic Surplus Changes and Overall Net-Gain for Scenario Four	64
Table 4.8 Distribution of Producer Gains for Scenario Four	64

Glossary

AGC: African Groundnut Council.

ARB: Arachide de Bouche.

CERAAS: Centre d'Etude Régional pour l'Amélioration de l'Adaptation à la Sécheresse (Regional Drought Resistance Study Center), Senegal.

CIRAD: Centre de coopération internationale en recherche agronomique pour le développement (The International Co-operation Center in Agronomic Research for Development).

CNIA: Comite National Interprofessionnel de L'Arichide (National Interprofessional Groundnut Committee), Senegal.

CODEX: Codex Alimentarius Commission

DFID: Department for International Development, the United Kingdom.

DPI: Department of Primary Industries, Queensland.

ECOWAS: Economic Community of West African States.

EIU: Economist Intelligence Unit.

ENEA: Ecole Nationale d'Economie Appliquée (School of Applied Economics), Senegal.

ESAF: Enhanced Structural Adjustment Facility.

EXTOXNET: Extension Toxicology Network

EU: European Union.

FAO: Food and Agriculture Organization.

FDA: Food and Drug Administration, US.

GTN: Global Trade Network.

ICRISAT: The International Crops Research Institute for the Semi-Arid Tropics.

IFPRI: International Food Policy Research Institute.

IFS: International Financial Statistics.

IMF: International Monetary Fund.

ITDG: Intermediate Technology Development Group.

NOVASEN: Nouvelles Arachides de Senegal.

OPS: Organismes Prives Stockeurs.

SAP: Structural Adjustment Program.

SONACOS: Societe Nationale de Commercialisation des Oleginuex due Senegal.

SONAGRAINES: Societe Nationale d'Approvisionnement en Graines.

SPS: Sanitary and Phytosanitary.

STABEX: Stabilisation des Recettes d'Exportation, an European Union funding facility.

TBT: Technical Barriers to Trade.

USAID: United States Agency for International Development.

USDA: United States Department of Agriculture.

WISARD: Web based Information System for Agricultural Research for Development.

WTO: World Trade Organization.

CHAPTER ONE: INTRODUCTION

1.1 Introduction

With the general worldwide decline in the imposition of tariffs, technical barriers to trade have become a common feature of global trading relations. While the justification for some of these barriers is subject to debate, some barriers are generally perceived to be appropriate¹, especially when they attempt to safeguard human, animal, or plant health. This appropriateness generally explains the rising importance of sanitary and phytosanitary (SPS) standards affecting the international trade in agricultural products. One such product is groundnuts, a product whose cultivation and storage is susceptible to serious contamination, capable of causing severe harm to human and animal health.

Groundnuts (also known as peanuts) are edible seeds produced by *Arachis hypogaea*, a tender herbaceous plant cultivated widely in tropical and sub-tropical developing countries (Maftai 1999). Most of the world's groundnuts are produced and consumed in developing countries, where they usually serve as a staple food. In developed countries, groundnuts are often used in confectionery and chocolate-based products. They constitute a valuable source of proteins, fats, energy, and minerals (Maftai 1999). Groundnuts are also crushed to extract groundnut oil, the residual meal serving as animal feed.

The groundnut industry has been grappling with the issue of the health hazards posed by aflatoxin-contaminated groundnuts and groundnut products. This issue has led to various restrictions by developed countries on imports of groundnuts. Given that the economies of many developing countries are very much dependent on groundnut exports to industrialized countries, there is the need for these less-developed economies to adopt aflatoxin-reducing technologies if their groundnut exports are to meet the regulatory standards of the importing countries. One such developing country is Senegal, a country whose major cash crop is groundnuts. This study attempts to assess the potential impact of research into aflatoxin reduction in Senegal's confectionery groundnut sector.

¹ Even if the general principle of the technical barrier is deemed appropriate, the specific magnitudes of the regulatory standard(s) may be very debatable.

1.2 Problem Statement

Aflatoxins are a group of closely related toxic compounds produced by certain strains of the fungi *Aspergillus flavus* and *Aspergillus parasiticus*. Under favorable conditions, these fungi grow on certain foods and feeds, leading to the production of aflatoxins. Conditions favorable to the growth of the aflatoxigenic fungi include high temperatures and humid environments. Foods that are particularly susceptible to being contaminated by aflatoxins include groundnuts, maize, cottonseed, and tree nuts. Members of the aflatoxin group include aflatoxins B1, B2, G1, G2, M1, and M2. Aflatoxin B1 is, however, often the predominant and most toxic. Poisoning resulting from ingestion of aflatoxins in contaminated food or feed, is known as aflatoxicosis. According to the US Food and Drug Administration (2002), no animal species is resistant to the severe toxic effects of aflatoxins; in a number of animal species, aflatoxins produce acute necrosis, cirrhosis, and carcinoma of the liver. Thus, even though aflatoxicosis in humans has seldom been reported², it is widely believed that humans are not exempt from the potential carcinogenic effects of aflatoxins. In developed countries, the levels of aflatoxin contamination in foods are usually not high enough to cause severe aflatoxicosis in humans. In less developed countries however, human vulnerability can vary with age, health, and level and duration of exposure (US Food and Drug Administration, 2002). Despite the carcinogenic effects of aflatoxins in animals, the US Food and Drug Administration (FDA) permits low levels of aflatoxins because they are considered unavoidable contaminants of certain foods.

Much literature exists on the various ways of reducing the aflatoxin content of foods and feeds. These include the adoption of appropriate farming and processing practices, the use of ammonia, and biological control. The reduction of aflatoxin contamination in crops can be achieved by the adoption of better harvest management techniques. For example, in Australia, aflatoxin contamination in groundnuts has been reduced through a harvesting technique that speeds up the rate of pod drying. This harvesting technique entails timely cutting, the use of inverted windrows, short thrashing

² According to the US Food and Drug Administration (2002), many cases of aflatoxicosis outbreaks in humans go unnoticed because medical services are less developed in the areas of the world where high contamination of aflatoxins occur in foods.

intervals, and artificial drying (Queensland Government 2001). Jones, Wineland, Parsons, and Hagler (1996) have shown that the potential exists for using chicken litter to detoxify aflatoxin-contaminated crops. In laboratory and field experiments, the incubation of contaminated maize with poultry litter resulted in the elimination of aflatoxin after a number of weeks.

Biological control of aflatoxin production is one of the most promising technologies. Of particular significance is the invention of Cole, Dorner, and Blankenship³ that controls the pre-harvest accumulation of aflatoxin in soil-borne crops by pitting harmless rival fungi against the aflatoxigenic fungi. By replacing the toxic strains of *Aspergillus parasiticus*, the harmless fungi are shown to inhibit aflatoxin production in the soil environment. It is worth noting also, that some Peanut CRSP⁴ projects are focused on eradicating aflatoxin in groundnuts. Potential technologies being explored by these projects include appropriate agronomic and post-harvest practices, the use of genetic engineering, and biochemical techniques (Peanut CRSP 2002).

At this point in time, it appears that none of the available technologies enjoys a clear superiority over the others. The choice of any aflatoxin-reducing technology or program will depend on factors such as the crop or feed in question, the monetary cost of the adoption, and the extent to which the technology will be acceptable to the society concerned. In general, the optimal choice in any given scenario would presumably involve a mix of technologies.

As noted earlier, concern over the health hazards of aflatoxin-contaminated foods and feeds, has led to the imposition of technical barriers to trade in certain food items. For instance, the European Union (EU) has set a new harmonized aflatoxin standard for European food imports. In general, a more stringent standard on aflatoxin B1 is applied to food products intended for direct human consumption, compared to the standards applied to food products that are to undergo further processing (Otsuki, Wilson, and Sewadeh 2001a). The various aflatoxin standards for groundnuts set by the European Union, the

³ Patented in 1994.

⁴ Peanut Collaborative Research Support Program.

United States, and the Codex Alimentarius Commission (CODEX)⁵, are presented in Table 1.1.

Table 1.1 Aflatoxin Maximum Admissible Levels (in ppb⁶)

Country/Organization	Product	Aflatoxin B1	Aflatoxin B1+B2+G1+G2
European Union	Groundnuts intended for direct human consumption or as an ingredient in foodstuffs.	2	4
	Groundnuts to be subjected to sorting, or other physical treatment, before human consumption or use as an ingredient in foodstuffs.	8	15
USA	Groundnuts		20
CODEX	Groundnuts		15

Sources: Otsuki, Wilson, and Sewadeh (2001b) and European Commission Regulation No. 1525/98, cited in Otsuki, Wilson, and Sewadeh (2001a).

The West African country of Senegal has for decades, depended on groundnuts as its leading cash crop. Over the years, the vagaries of the Sahelian weather have contributed to considerable fluctuations in Senegal’s groundnut output. The success of Senegal’s groundnut sector is undeniably dependent on the implementation of appropriate economic policies. Nevertheless, future success in the sector would be very limited in the absence of research into aflatoxin reduction. This need for aflatoxin-reducing research stems from the growing concern over the levels of aflatoxin contamination in groundnuts (and other food) exports, thus leading to the imposition of sanitary and phytosanitary

⁵ The Codex Alimentarius Commission is the body in charge of compiling the standards, codes of practice, guidelines and recommendations that constitute the Codex Alimentarius (a Latin expression meaning “food code”).

⁶One ppb (part per billion) is equivalent to less than 1 drop in 10,000 gallons.

(SPS) standards by the European Union and other industrialized countries. Given that Europe is the most important market for African countries, the imposition of strict aflatoxin standards by the EU and other developed countries would adversely affect Senegal's economy (Otsuki, Wilson, and Sewadeh 2001a). Therefore, immense benefits can potentially be derived from research into aflatoxin-reducing technologies. These benefits include reduced risks of cancer in animals and humans and a greater access to the groundnut export market.

In Senegal, the confectionery groundnut sector is mainly export-oriented. Thus, the sector's success depends on ensuring that groundnuts produced meet importers' (mainly the EU) strict aflatoxin-regulatory standards. Consequently, in 2000, research commenced on the development of an aflatoxin-reducing program for the sector. The research is being conducted by the International Co-operation Center in Agronomic Research for Development (CIRAD) within the context of a much broader program. CIRAD's overall research program has many components. These components include seed and plant health, mitigation of drought stress, post-harvest management, the identification and multiplication of new groundnut cultivars, the development of a GAP⁷ guide for confectionery groundnut production, a HACCP⁸ analysis of the major Senegalese groundnut processing plants, and the upgrading of Senegal's confectionery groundnut regulation. The determination of the economic impact of CIRAD's aflatoxin-reducing research depends on a careful evaluation of all potential benefits and costs of the research and program adoption. The ex-ante nature of the analysis injects an element of uncertainty into the evaluation, thus lending itself to the examination of different scenarios. The economic evaluation of CIRAD's aflatoxin research is of significant importance in informing policy discussion on the adoption and management of the program.

1.3 Objectives

This study aims at evaluating, for Senegal's confectionery groundnut sector, the potential economic impact of research into the development of an aflatoxin-reducing

⁷ That is, good agricultural practices.

⁸ An acronym for Hazard Analysis and Critical Control Point, a state-of-the-art approach to food safety.

program. Even though the program is likely to generate some health impact, an analysis of these health effects falls outside the scope of the present study. Issues to be addressed in this study include the following:

- i) The potential impact of CIRAD's research on Senegal's confectionery groundnut producers.
- ii) The potential effect of the research on Senegal's confectionery groundnut consumers.
- iii) The potential overall impact of the research on Senegal's confectionery groundnut sector.

1.4 Hypotheses

Underlying the study are the following hypotheses:

- (i) The adoption of CIRAD's aflatoxin-reducing program would enhance the welfare of Senegal's confectionery groundnut farmers.
- (ii) An overall welfare net-gain would be derived by Senegal from the adoption of the program.

1.5 Methods

Economic surplus analyses would be employed to project the potential impact (on Senegal's confectionery groundnut sector) of CIRAD's research into the development of an aflatoxin-reducing program. Since Senegal's confectionery groundnuts are sold on the export and domestic markets, a two-sector model would be used. The analysis would capture changes in producer and consumer surpluses associated with the potential program adoption. The overall impact on Senegal's economy would be determined by aggregating the net economic surplus changes in the export and domestic sectors.

1.6 Organization

In the next chapter, a review of Senegal's groundnut sector is carried out. This review is followed by a discussion of the methodology to be employed in the analyses. The fourth chapter is a presentation and discussion of results of the data analyses, while a summary and concluding remarks are presented in the fifth and final chapter.

CHAPTER TWO: AN OVERVIEW OF SENEGAL'S GROUNDNUT SECTOR

2.1 Introduction

This chapter reviews the groundnut sector in Senegal in order to lay the foundation for the empirical model. As a prelude to this overview, the West African groundnut industry will be briefly discussed. In examining Senegal's groundnut sector, we would focus on some of the macroeconomic developments, as well as, the production, marketing, and pricing of groundnuts. Groundnut aflatoxin research in Senegal and West Africa would also be discussed.

2.2 The West African Groundnut Industry

Since the introduction of groundnuts to West Africa by the Europeans in the 16th century, its cultivation has assumed significant importance in a number of West African countries. Currently, groundnuts constitute an important food staple and cash crop in several West African countries, notably, the Gambia, and Senegal. In the 1960s and 1970s, the share of groundnuts and their products in the export revenues of the African Groundnut Council (AGC) countries⁹ ranged between 40 and 90 percent. Since the 1970s however, annual aggregate exports of shelled groundnuts have fallen by 15 percent, unshelled groundnuts by 10 percent, and groundnut oil by 4 percent (IFPRI 1994). While changes in the global groundnuts market may have contributed to the decline in AGC export performance, it has been suggested that domestic policies in individual AGC countries had a greater influence (Badiane and Kinteh 1994). The need for a favorable international trade climate notwithstanding, the success of the groundnut sector in West Africa hinges critically on the formulation and implementation of appropriate domestic policies.

⁹ The AGC countries are made up of the Gambia, Mali, Niger, Nigeria, Senegal, and Sudan.

2.3 Senegal's Groundnut Sector

2.3.1 Some Macroeconomic Developments

The importance of groundnuts to Senegal's economy can hardly be overemphasized. At the time of independence (1960), groundnuts represented over 80 percent of the country's exports, covered half the cultivated area, and employed 87 percent of the active population (Caswell 1985). Senegal's groundnut sector has, however, had a checkered history. Prior to the attainment of independence, the dominant crop in Senegal was groundnut. The post-independence policy on the groundnut sector was one of massive governmental dominance. This dominance was influenced by the government's professed philosophy of "African socialism", which in practice, translated into massive state intervention and an inward-looking economic strategy (EIU, 2002). Between 1960 and 1965, the sector was nationalized, with marketing, credit programs, pricing, and input distribution falling under the ambit of the government. Policies pursued during this period included, price subsidization and easy access to credit. These policies, coupled with favorable weather conditions, seemed to have benefited the sector, as groundnut output increased significantly. The period 1966-78 was, however, one of declining fortunes for Senegal's groundnut industry. The inefficiencies associated with governmental control began to emerge with bouts of unfavorable weather. This era was characterized by widespread credit default and an institutional crisis.

Given the above developments in Senegal's groundnut sector and the general decline in the economy, it is not surprising that the government embraced a World Bank/IMF Structural Adjustment Program (SAP) in 1979. The main aim of the SAP has been the promotion of growth and development, which in turn is to be achieved through a reduction in governmental role in the economy, an improvement in public sector management, an enhancement in incentives for private sector participation, and poverty reduction (US Department of State, 2002). With respect to the groundnut sector, the reforms were mainly to replace the many years of heavy government intervention in the groundnut market. The government of Senegal thus initiated a process that was to reform the marketing of groundnuts. It was envisaged that with the privatization of groundnut marketing, efficiency would be enhanced. There seems to have been considerable reluctance (on the part of the government) to embark on a comprehensive liberalization

of the groundnut sector; in spite of the reforms, the processing of groundnuts has still been under the control of the state. As noted by IFPRI (1997), the partial reforms adopted by the government of Senegal entailed the following:

- i) excluding the processing sector from the liberalization process;
- ii) the involvement of the government in the procurement of unshelled groundnuts through farmer cooperatives and a contract mechanism that permits its marketing board to exert control over licensed traders;
- iii) the fixing of pan-territorial and pan-temporal producer prices; and
- iv) the accommodation of extant, albeit not enforced, pre-reform limitations on the movement of commodities.

As of the early 1990s, the results of the Structural Adjustment Program were mixed. Even though there had been some growth in the economy, as well as, a reduction in the state's role in agriculture, there had been no reduction in public expenditure, and the diversification of the economy had been constrained. These actions, coupled with the appreciation of the CFA franc, led to a huge buildup of government debt. In January, 1994, Senegal, in line with other members of the Franc Zone, agreed reluctantly to a 50% devaluation of the CFA franc (EIU, 2002). In 1994, Senegal renewed her commitment to the pursuit of free-market reforms by accepting an IMF-supported Enhanced Structural Adjustment Facility (ESAF). According to EIU (2002), the policy conditions attached to the ESAF included the following:

- i) the liberalization of labor legislation, prices and external trade;
- ii) agricultural reform and the stimulation of market mechanisms; and
- iii) the restructuring of the public sector, including a round of privatizations.

In April 1998, a new three-year ESAF (subsequently renamed the poverty reduction and growth facility) was signed with the IMF and its duration was later extended for another year, until mid-April 2002 (EIU, 2002).

2.3.2 Groundnut Production

Senegal's groundnut output has fluctuated over the years, with production levels reaching a peak of 1,444,093 tons in 1975, and falling to its lowest point (503,770 tons) in 1984 (see Table 2.1 and Figure 2.1). Factors accounting for these variations in output

include the vagaries of the Sahelian weather and variations in the volume sold by farmers through official channels, the latter depending on the producer prices announced (EIU 2002). Groundnut production in Senegal is mainly concentrated in the Groundnut Basin. The Groundnut Basin is subdivided into the following regions: Northern, Central, Southern Groundnut Basin, the Senegal River Basin, Eastern region, and Casamance.

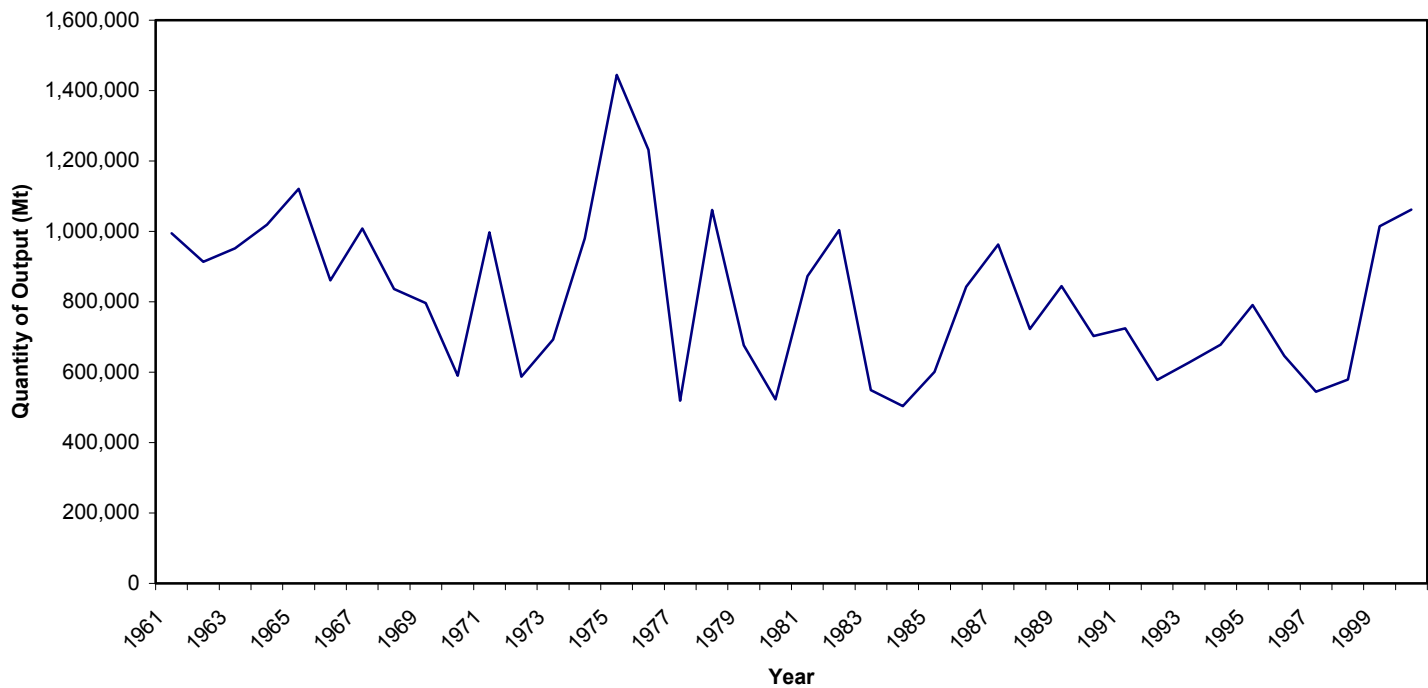
Table 2.1 Senegal's Groundnut Production

Year	Production (MT)	Year	Production (MT)	Year	Production (MT)
1961	995,000	1975	1,444,093	1989	844,225
1962	914,000	1976	1,231,500	1990	702,584
1963	952,000	1977	518,956	1991	724,416
1964	1,019,000	1978	1,061,082	1992	578,498
1965	1,121,000	1979	676,000	1993	627,633
1966	860,670	1980	523,003	1994	678,040
1967	1,008,610	1981	872,319	1995	790,617
1968	836,800	1982	1,004,023	1996	646,394
1969	796,100	1983	549,000	1997	544,825
1970	589,950	1984	503,770	1998	579,067
1971	997,120	1985	601,246	1999	1,014,250
1972	586,900	1986	842,564	2000	1,061,540
1973	692,779	1987	963,123		
1974	980,200	1988	722,898		

Source: Food and Agriculture Organization (FAO), 2002.

About two-thirds of Senegal's active population is found in the groundnut basin, while the region accounts for 80 percent of the country's groundnut production. The Groundnut Basin is characterized by poor soils, low and unpredictable rainfall, and poor vegetation, thus rendering increased groundnut production daunting. Groundnut production in

Figure 2.1 Senegal's Groundnut Output



Senegal, being typical of agricultural production in Africa, is characterized by a labor-intensive and rudimentary technology. Small-scale farmers carry out production, and tools employed are usually non-motorized (Soufi 2001), with animal traction being commonly used. As noted by Badiane (2001), most Senegalese groundnut farmers rely on horses and donkeys. According to Bergtold (2001), Senegalese farmers produce three primary types of groundnuts. These are oil groundnuts (arachide huilerie), confectionery groundnuts (arachide de bouche), and seed groundnuts (arachide semences). The dominant type is oil groundnuts, followed by confectionery groundnuts, and seed groundnuts in that order.

Given the low organic content matter in soils in Senegal, the use of fertilizers is one major means of ensuring soil quality. The major fertilizers used for groundnut production in Senegal include phosphorus, calcium and sulfur (Badiane 2001). The use of fertilizers by Senegalese groundnut farmers has however, been far from optimal. Notwithstanding this, some modest gains were made in the use of fertilizers during the implementation of subsidy schemes. In the absence of such schemes, however, the use of

fertilizers decreased. This decline in fertilizer usage was the experience in the 1980s following the implementation of the structural adjustment program. According to USAID data reported in Badiane (2001), fertilizer consumption decreased from 69,800 to 29,100 metric tons between 1980 and 1989. In general, Senegalese groundnut farmers have not made much use of fertilizers, pesticides, fungicides, and soil conservation technology. As a result, there has been a decrease in soil fertility, leading to a decline in groundnut yield (Soufi 2001).

One of the biggest obstacles to groundnut production in Senegal is persistent droughts and inadequate rainfall. The average annual rainfall requirement for groundnut production is 600 – 1200 mm, but Senegal receives 500 – 700 mm on average (Badiane 2001). This low rainfall naturally poses a big challenge to groundnut cultivation in Senegal. Another factor hampering groundnut production in Senegal is high prices of seeds and other inputs. These high input prices have accounted for much of the fall in groundnut output. According to Badiane (2001), seed prices range between 90 CFA Franc/kg (for unshelled groundnuts) and 200 CFA Franc/kg (for shelled groundnuts). Crop diseases and pests further adversely affect groundnut output. One strategy, by which Senegalese groundnut farmers have been trying to compensate for crop losses caused by diseases and pests, is the practice of intercropping groundnut with millet or sorghum. Apart from acting as an insurance against crop failures, this practice can raise returns to land. It also decreases soil erosion and provides better nutrition to farming households due to the variety of food crops (Badiane 2001).

Aflatoxin contamination of groundnut crops is obviously, another major problem facing Senegal's groundnut sector; apart from its serious health hazards, it significantly restricts the volume of groundnut exports. This restriction in groundnut exports is particularly serious, because of the European Union's imposition of a new aflatoxin regulation, which is stricter than that suggested by the Codex Alimentarius Commission¹⁰. It is worth noting that the problem of aflatoxin contamination of Senegalese groundnuts is, to a large extent, confined to confectionery groundnuts; seed groundnuts are mainly used for re-planting, while in the case of oil groundnuts, most of

¹⁰ The Codex Alimentarius Commission is the body in charge of compiling the standards, codes of practice, guidelines and recommendations that constitute the Codex Alimentarius (a Latin expression meaning "food code").

the toxins are eliminated during the oil extraction process (Soufi 2001, Badiane 2001, and Bergtold 2001). The potential seriousness of the export-restricting effect of aflatoxin contamination in the groundnut sectors in Senegal and other African countries has been documented in a number of studies (Otsuki, Wilson, and Sewadeh 2001a, Otsuki, Wilson, and Sewadeh 2001b, and Bergtold 2001). The papers by Otsuki, Wilson, and Sewadeh (2001a, 2001b) are among the pioneering studies into the impact of developed countries' strict aflatoxin standards on exports from the developing world. They highlight the huge losses in export revenue that African groundnut exporters are likely to incur from the imposition of a very stringent aflatoxin regulation. Otsuki, Wilson, and Sewadeh (2001a) have noted that, in comments submitted to the World Trade Organization (WTO), — in response to the then European Union's new aflatoxin standard — a representative of the Gambia observed that the new standard would “*effectively restrict entry of the Gambia's groundnuts and essentially the groundnuts from producer countries in the developing world to the European Union*” (WTO, G/SPS/GEN/50, 1998).

2.3.3 Marketing of Groundnuts

Since 1840, when Senegal's first groundnuts were exported to France, Senegalese peasant groundnut farmers have been incorporated into a market economy (Sall 1996). This incorporation into the market has been due to the determination to develop groundnuts into a major foreign exchange earner. With the confirmation of Senegal's single-crop policy after independence, the marketing of groundnuts became firmly established (Sall 1996). In Senegal, groundnuts are sold through two main channels, the formal and informal channels. The informal sector is largely, a gray market while the formal channel is made up of the following:

- i) Societe Nationale de Commercialisation des Oleginuex due Senegal (SONACOS), the state-owned agro-industrial group.
- ii) Nouvelles Arachides de Senegal (NOVASEN), a privatized subsidiary of SONACOS that deals mainly in confectionery groundnuts.

- iii) Societe Nationale d'Approvisionnement en Graines (SONAGRAINES), a public seed distribution company¹¹
- iv) Organismes Prives Stockeurs (OPS), i.e., private sector agents, and
- v) farm cooperatives.

SONACOS is a very dominant player in the groundnut oil market. It is Senegal's major supplier of groundnut oil to the European Union (EU) and has an estimated 90 percent share of the domestic edible oil industry (OT Africa Line 2002). Besides crushing groundnuts for oil and meal, SONACOS refines the oil, manufactures peanut cake for animal feeds, trades in groundnut oil and vegetable oil products, and is also involved in the manufacture of soaps and margarines (OT Africa Line 2002).

The formal marketing companies only accept unshelled groundnuts during five months in a year (December through April), while the informal market is active all year round (Soufi 2001). Even though most (91 percent) of the groundnuts sold on the informal market are unshelled, producers may add value to their output by shelling the groundnuts or transforming them into paste or oil, and selling them on the informal market (Soufi 2001). As noted earlier, the three types of groundnuts cultivated in Senegal are oil groundnuts, confectionery groundnuts, and seed groundnuts. Oil groundnuts are destined for the oil extraction industry, while confectionery groundnuts are partly exported and partly processed into edible groundnut products and marketed locally. Seed groundnuts are usually marketed to farmers for replanting.

The cooperatives, licensed private sector agents, and the informal traders purchase oil groundnuts (shelled and unshelled) directly from the farmers. With the exception of the groundnuts purchased by informal traders, these groundnuts are in turn sold to SONACOS, who process them into groundnut oil and groundnut meal. Groundnut oil manufactured by SONACOS is exported, while the groundnut meal is sold both on the exports and domestic markets. The oil groundnuts sold to the informal traders are mainly purchased by NOVASEN, who subsequently process them into groundnut oil and groundnut meal for sale on the domestic market (Bergtold 2001). With regard to seed groundnuts (shelled and unshelled), private agents and the informal traders purchase them

¹¹ In November 2001, the government of Senegal decided to dissolve SONAGRAINES and to cede their activities to the private sector (EIU 2002).

directly from the farmers for storage and resale the following year. Significantly, seed groundnuts are not exported, since they are produced and consumed exclusively within the country (Bergtold 2001).

The direct purchase of confectionery groundnuts from farmers is carried out mainly by NOVASEN. NOVASEN is a private firm, which assumed control of Senegal's confectionery groundnut program in 1990 (Warning and Key 2002). It dominates the purchasing of confectionery groundnuts through its Arachide de Bouche (ARB) program. The ARB program is a contract-farming scheme that employs many local agents to inspect the farming practices (Warning and Key 2002). According to Warning and Key, the duties of the agents include the following:

- (a) selection of contracting farmers and organizing them into groups;
- (b) provision (on credit, at 13 percent interest rate) of inputs such as, seeds, fertilizer, and agro-chemicals;
- (c) monitoring the harvest and the handling of the product; and
- (d) enforcing debt repayment at harvest time.

Senegal's confectionery groundnuts are mainly exported to the European Union, while some are processed into confectionery products for sale on the domestic and foreign markets. Some of the confectionery groundnuts are however, kept for self-consumption by the farmers. According to Bergtold (2001), Senegal's share of exports of confectionery groundnuts to the EU is very low. Thus, Senegal can hardly influence the world market price of confectionery groundnuts. There is, nevertheless, significant potential for confectionery groundnuts to assume a prominent position in Senegal's groundnut sector. For this potential to be fully realized, there is the need for the country to deal effectively with the export-restricting problems posed by aflatoxin contamination of confectionery groundnuts. A major cause of this problem is technological. In the words of Otsuki, Wilson, and Sewadeh (2001b, p.280), "*... analytical methods used to detect aflatoxin levels in food products have developed much more quickly in developed countries than have farming methods in developing countries. The availability of sensitive equipment has allowed developed countries to implement increasingly strict standards on aflatoxins, making it progressively more difficult for exporting countries to comply with such standards.*" Otsuki, Wilson, and Sewadeh (2001a) suggest that, in

comparison with the standards recommended by the Codex Alimentarius Commission, the new European Union Aflatoxin regulation will lead to a 64 percent decrease in African exports of cereals, dried fruits and nuts to Europe. The study's estimated loss in Africa's export revenue associated with the new EU regulation is US\$670 million. It should be noted also, that Senegal, like other African groundnut exporters, is highly dependent on Europe for her groundnut exports. As shown in Table 2.3, the European market accounts for 56 percent of the value of Africa's edible groundnut exports, while the corresponding figures for groundnut oil, and groundnuts for oil seeds are 61 percent and 74 percent respectively. Given Senegal's high dependence on Europe for the exports of groundnuts, strict aflatoxin-regulatory standards on groundnuts will have a significant adverse effect on the Senegalese economy.

Table 2.2 Senegal's Groundnut Exports

Year	Exports (MT)	Exports (1000\$)	Year	Exports (MT)	Exports (1000\$)	Year	Exports (MT)	Exports (1000\$)
1961	269,436	46,343	1975	9,484	6,184	1989	11,373	6,113
1962	276,673	47,690	1976	109,263	56,156	1990	19,347	10,664
1963	203,606	35,251	1977	71,365	37,149	1991	13,356	8,084
1964	213,861	36,884	1978	5,209	3,511	1992	11,913	6,296
1965	216,845	37,338	1979	9,126	8,651	1993	2,810	1,583
1966	298,086	52,220	1980	2,729	2,202	1994	6,549	3,841
1967	181,082	31,486	1981	2,843	3,172	1995	6,617	3,671
1968	243,115	33,330	1982	2,602	1,061	1996	20,000	10,000
1969	96,453	15,923	1983	23,956	10,423	1997	5,762	3,231
1970	53,722	10,349	1984	17,054	9,725	1998	5,290	2,784
1971	32,828	6,699	1985	439	263	1999	7,419	3,872
1972	14,390	3,953	1986	668	528	2000	1,792	1,449
1973	4,304	1,886	1987	1,268	767			
1974	9,917	5,843	1988	827	446			

Source: Food and Agriculture Organization (FAO), 2002.

Senegal's groundnut exports have undergone a drastic decline over the years. The quantities of exports were at their peak for a greater part of the 1960s. Since the late 1960s however, there has been a general decline in the quantities of groundnuts exported. As can be observed from Table 2.2 and Figure 2.2, during the period 1968 – 1973, the quantity of Senegal's exports dropped sharply from 243,115 tons to 4,304 tons. Since

1978, the quantities of groundnuts exported by Senegal in any given year have not exceeded 25,000 tons. Thus, unlike the groundnut production trend, Senegal's exports (quantity) of groundnuts have been falling considerably over the years. It should be noted though, that the trends in exports (quantity) of groundnut oil and groundnut cakes have not been as dismal as that of raw groundnuts (see Figure 2.3). Unlike the exports of groundnuts, exports of groundnut oil and groundnut cakes have in general, not been declining sharply. Figure 2.4 depicts a comparison of the exports (value) of groundnuts, groundnut oil, and groundnut cakes. Of the three groundnut products, groundnut oil is the highest contributor to Senegal's export revenue. Between raw groundnuts and groundnut cakes, the former generated more export revenue in the 1960s. Since 1970 however, groundnut cake exports have, on the whole, generated more revenue for the Senegalese economy than the exports of raw groundnuts.

Figure 2.2 Senegal's Quantity of Groundnut Exports

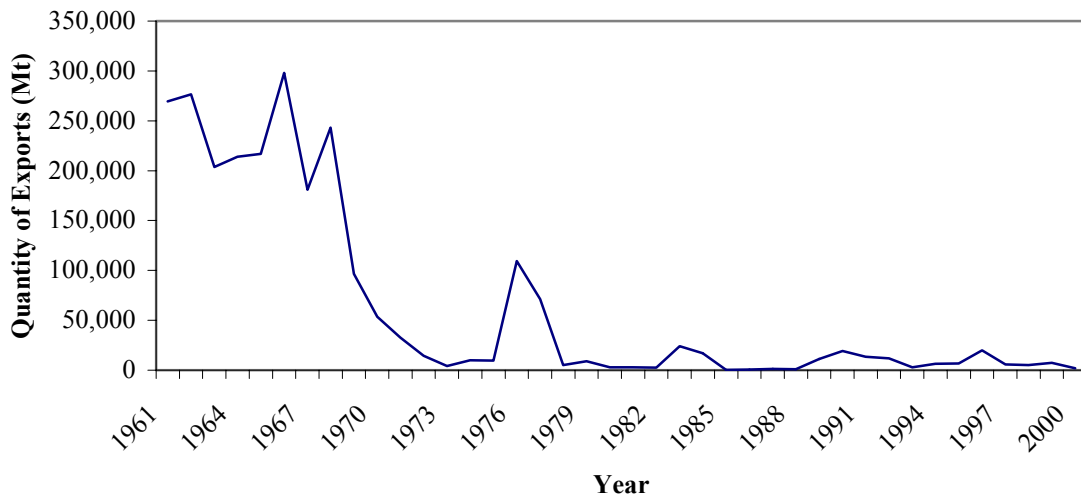


Figure 2.3 Senegal's Groundnut Production and Exports of Groundnut Products

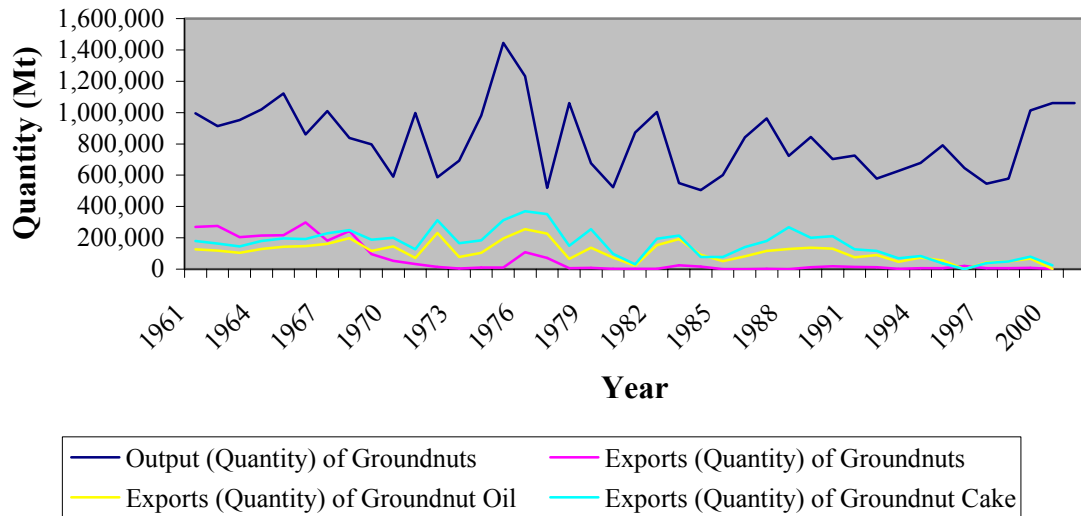


Figure 2.4 Senegal's Exports (Value) of Groundnut Products

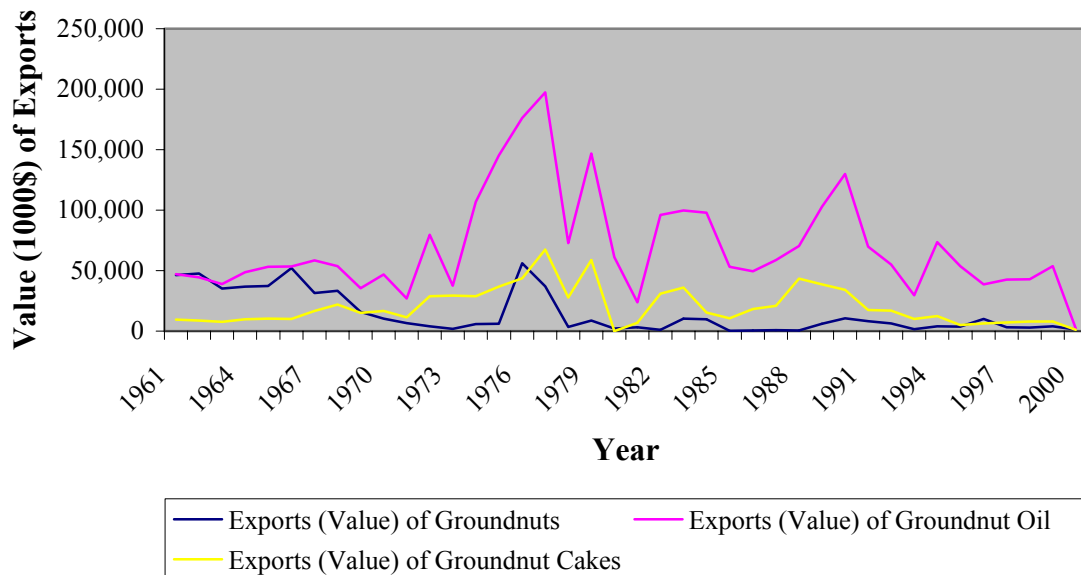


Table 2.3 Share of Export Value of Groundnut Products by Destination: 1985-98

	Edible groundnuts (%)	Groundnut Oil (%)	Groundnuts for oil seeds (%)
East Asia and Pacific	27	30	15
European	56	61	74
Middle East	2	3	10
North America	14	4	-
Rest of the World	1	2	1

Source: Computed by Otsuki, Wilson, and Sewadeh (2001b) from United Nations COMTRADE Records.

2.3.4 Groundnut Pricing

Senegal has very little control over the pricing of groundnuts on the international market. This lack of control is due to the fact that its exports constitute a small percentage of the world market. The (producer) price received by Senegalese groundnut farmers is nevertheless, highly influenced by the country's political authorities. Between 1960 and 1996, the government determined the producer price of groundnuts (Bergtold 2001). According to Caswell (1985), prior to 1967/68, the official producer price for groundnuts was determined on the basis of the CIF groundnut price in Marseilles (itself fixed by the French government above world market levels for raw materials imported from the former colonies). Some deductions¹² were then made before the final producer price was established. After a brief experimentation with regional pricing, a single national producer price was set with effect from the 1971/72 farming season (Caswell).

The role of the Senegalese government in the setting of the producer price of groundnuts enabled it to raise revenue by setting the price below the world market price. It has been observed that there have been instances where the world market price fell below the fixed producer price, and as a result, Senegalese groundnut farmers were subsidized, instead of being taxed (Claasen and Salin 1991, cited in Bergtold 2001). Since 1996, the setting of the producer price for groundnuts has been under the control of

¹² Caswell (1985) explains that shipping, insurance, and handling costs were subtracted according to a fixed formula to yield a theoretical delivery price to the factory or quayside, and this figure worked back to each collection point.

an inter-professional committee. This arrangement appears to be an attempt to lessen the role of the Senegalese Government in the setting of the producer price of groundnuts. The committee, known (in French) as Comite National Interprofessionnel de L'Arichide (CNIA), is made up of representatives of the government, SONACOS, the private sector, and farmer cooperatives (Gaye 2000, Senegal 2000, cited in Bergtold 2001). The producer prices (in both nominal and real¹³ terms) for groundnuts between 1971 and 1995 are shown in Table 2.4 and Figure 2.5. Even though in nominal terms, the producer price shows an upward trend, the opposite holds in real terms.

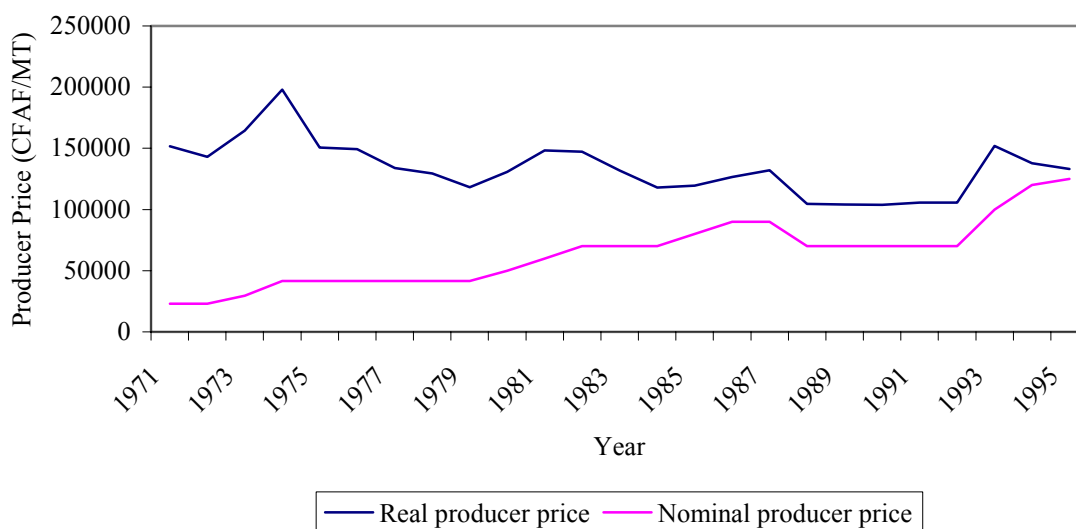
Table 2.4 Senegal's Groundnut Producer Price (CFAF/MT)

Year	Producer price (nominal)	Producer price (real)	Year	Producer price (nominal)	Producer price (real)
1971	23,100	151,761.3	1984	70,000	118,068.1
1972	23,100	142,938	1985	80,000	119,416.5
1973	29,500	164,381.4	1986	90,000	126,535
1974	41,500	198,064.8	1987	90,000	131,938
1975	41,500	150,745.6	1988	70,000	104,489.5
1976	41,500	149,217.7	1989	70,000	104,051.7
1977	41,500	133,843.8	1990	70,000	103,761.8
1978	41,500	129,526.2	1991	70,000	105,525.5
1979	41,500	118,097.5	1992	70,000	105,675.2
1980	50,000	130,749.4	1993	100,000	151,826
1981	60,000	148,162.4	1994	120,000	137,773.5
1982	70,000	147,235.2	1995	125,000	133,037.5
1983	70,000	131,860.2			

Source: Obtained or computed from FAO's FAOSTAT, and IMF's International Financial Statistics 2001 Yearbook.

¹³ The base period is 1998-2000.

Figure 2.5 Senegal's Groundnut Producer Price



2.4 Groundnut Aflatoxin Research in Senegal and West Africa

The determination to minimize groundnut aflatoxin contamination in West Africa has spawned several research efforts. Institutions involved in these efforts include USAID (through Peanut CRSP¹⁴), CIRAD¹⁵, ICRISAT¹⁶, and ISRA¹⁷. Potential technologies being explored include farming and post-harvest management practices, the use of biochemical mechanisms, and genetic control. After surveying research activities in West Africa, CIRAD's aflatoxin research in Senegal's confectionery groundnut sector will be discussed, since that is central to this study.

2.4.1 Groundnut Aflatoxin Research in West Africa

Some Peanut CRSP projects are currently focused on addressing the problem of groundnut aflatoxin contamination in West Africa. These include projects with Principal Investigators Dr. Keller (University of Wisconsin), Dr. Ingram (University of Georgia),

¹⁴ Peanut Collaborative Research Support Program.

¹⁵ Centre de coopération internationale en recherche agronomique pour le développement (The International Co-operation Center in Agronomic Research for Development).

¹⁶ The International Crops Research Institute for the Semi-Arid Tropics.

¹⁷ Institut sénégalais de recherches agricoles (Senegalese Institute for Agricultural Research).

and Dr. Phillips (University of Georgia). Dr. Keller, in collaboration with scientists in Ghana, is exploring the possibility of developing a genetic technology for eliminating aflatoxin in groundnuts. Using genetic engineering technology, the team hopes to develop a technique for eliminating aflatoxin contamination in groundnuts. It is reckoned that the Keller-led research has the potential of identifying anti-fungal genes that may be effective against other fungal pathogens of groundnuts, besides *Aspergillus* (Peanut CRSP 2002).

In partnership with scientists in Benin and Mali, Dr. Ingram is carrying out research to assess the risk of pre-harvest aflatoxin contamination and to develop technologies for reducing aflatoxin contamination in groundnuts. A model of aflatoxin contamination in field and before storage would be developed and verified, using data from field research in Benin. Using data from field research in Mali, a model of aflatoxin contamination in stored peanuts would also be developed and verified. A controlled environment research project is to be conducted in Georgia to quantify relationships among environmental variables, *Aspergillus flavus* populations, and aflatoxin contamination. These relationships would be used to enhance risk models and algorithms (Peanut CRSP 2002).

Dr. Phillips, in collaboration with scientists in Ghana, has been investigating the prospects for eliminating aflatoxin from peanut meal. The means employed by the scientists has been extrusion cooking in the presence of lysine. The addition of lysine to contaminated peanut meal is to serve as a nucleophile for destroying aflatoxin, and also to improve protein quality. Results so far suggest a very tight binding of the toxins to peanut proteins. It is anticipated that scaling up to a larger, more intensive extruder may improve aflatoxin degradation. Results further suggest that the nutritional quality of detoxified peanut meals is equal (or superior) to that of control meal (Peanut CRSP 2002).

The determination to minimize groundnut aflatoxin contamination in West Africa has also received support from the Groundnut Network. The Groundnut Network is an international network of institutions committed to the promotion of groundnut production. The network gives priority to aflatoxin research, disease control, genetic improvement for drought resistance, and the development of cropping practices. The main source of funding for the network is the European Union, and its member

institutions include CIRAD and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). With the active participation of ICRISAT, the network plans to characterize groundnut resistance to *Aspergillus flavus* and to harmonize methods for analyzing aflatoxin (Coraf Action 1998). It is worth noting also, that ICRISAT, CIRAD, and several US universities are employing bio-technological techniques to create higher levels of resistance than is feasible through conventional breeding (ICRISAT 2002).

In an attempt to identify new tools for groundnut aflatoxin control in the Sahel regions of Africa, CERAAS¹⁸ is coordinating an international project with locations in France, Mali, Portugal, and Senegal. A primary objective of this project is to identify biochemical, physiological, and molecular resistance mechanisms of the host plant, in order to develop an integrated system for prevention and control of pre-harvest aflatoxin (WISARD 2002). The knowledge gained from the research is expected to contribute to the development of resistant groundnut varieties.

2.4.2 Aflatoxin Research in Senegal's Confectionery Groundnut Sector

Given that the international trade in confectionery groundnuts is characterized by stringent aflatoxin requirements, the need for Senegal to address aflatoxin contamination in confectionery groundnuts is obvious. This need received attention in 2000 with the commencement of research (by CIRAD) to address the problem. CIRAD's research is part of a confectionery groundnut project coordinated by Senegal's Groundnut Inter-professional Committee (CNIA). CIRAD is a French scientific organization specializing in agricultural research for the tropics and subtropics of the world. With researchers posted in 50 countries, CIRAD collaborates with national research organizations and provides technical support in development projects (CIRAD 2001). CIRAD's aflatoxin research is funded through international donor support.¹⁹ The expected duration of the research is 6 years.

So far, CIRAD has identified several issues that must be addressed in order to deal effectively with aflatoxin contamination in confectionery groundnuts. These issues include drought stress, plant health, and post-harvest management (Sagarra 2002b). It

¹⁸ Centre d'Etude Régional pour l'Amélioration de l'Adaptation à la Sécheresse (Regional Drought Resistance Study Center), Senegal.

¹⁹ As of November 2002, a break in funding had interrupted the research.

must be noted that CIRAD's aflatoxin-reducing research project is within the context of a broader program that addresses other related issues. The present study focuses more on the field-based component of CIRAD's research because of its direct bearing on the reduction of aflatoxin-contaminated confectionery groundnuts. Issues that fall under the ambit of CIRAD's overall research program include the following:

- i) the identification and multiplication of new peanut cultivars adapted to local conditions and with a high market potential
- ii) the development of a GAP guide for confectionery groundnut production
- iii) the development of a management tool for irrigated confectionery groundnut production²⁰
- iv) a HACCP²¹ analysis of the major Senegalese groundnut processing plants
- v) the development of quality guidelines for the national laboratory for aflatoxin analysis
- vi) the upgrading of the national edible peanut regulation, and
- viii) the evaluation of Senegal's groundnut production on the export market.

The contamination of groundnuts by aflatoxin-causing moulds can occur during plant growth (pre-harvest) or while drying or storing the pods (post-harvest). CIRAD's research is aimed at reducing both pre- and post-harvest aflatoxin contamination. The prevention of pre-harvest aflatoxin contamination is critical to success; once contamination occurs, it is impossible to completely eliminate the toxin (ITDG 2002). On the other hand, the importance of dealing with post-harvest contamination lies in the fact that, the proper handling and storage of harvested groundnuts can considerably reduce the problem of aflatoxin contamination. CIRAD's set of research recommendations has three main components, namely, seed and plant health, mitigation of drought stress, and post-harvest management. Each of these components is crucial to the success of the research.

CIRAD's recommended set of agricultural practices is, to a large extent, not sophisticated; it is an improvement over existing groundnut farming practices. Consequently, even though the adoption of the practices would increase production cost²², the percentage increase is not expected to be high. An important aspect of

²⁰ This may only be useful in principle, since the bulk of Senegal's confectionery groundnuts are produced under rainfed agriculture (Warning and Key 2002, and Sagarra 2002a).

²¹ An acronym for Hazard Analysis and Critical Control Point, a state-of-the-art approach to food safety.

²² The increased cost would mainly arise from the costs of new cultivars and the application of fungicide.

CIRAD's research is the identification and multiplication of new groundnut cultivars²³ adapted to local conditions and with a high market potential. The use of the new cultivars would enhance seed quality. CIRAD's research recommends the cleaning and harrowing of the soil before the seeds are sown (Sagarra 2002b). Furthermore, the groundnut seeds are to be treated with the pesticide, Granox (200g of Granox/100kg of seeds). The seed treatment is to ensure that the seeds attain the desired quality, thereby reducing the risk of aflatoxin contamination. In addition, the seeds are to be sown with a spacing of 50cm between rows and 15cm within rows. The research recommendations also entail the application of a fungicide (chlorothalonil). Chlorothalonil is a broad-spectrum organochlorine fungicide used to control fungi that threaten vegetables, trees, and other agricultural crops (EXTOXNET 1996).

Drought stress tends to render groundnuts susceptible to the aflatoxin-causing mould. A significant aspect of CIRAD's research is an assessment of the impact of drought stress on the aflatoxin contamination of confectionery groundnuts. In this respect, trials were conducted during the dry season, using irrigation, in order to evaluate production under different water regimes. CIRAD's research recommendations place considerable importance on the availability of the appropriate amount of moisture at the various stages of groundnut cultivation. As a result, it is recommended that seed planting be carried out only when the soil moisture is adequate (an equivalent of rainfall exceeding 20mm).

The post-harvest management of groundnuts consists of a range of practices crucial to the minimization of growth of the aflatoxin-causing mould. In order to prevent post-harvest aflatoxin contamination, CIRAD's research prescribes timely harvesting of the crop. Timely harvesting of groundnuts helps to reduce the moisture content of the nuts; it is generally recommended that, the moisture content should be less than 10 percent (ITDG 2002). CIRAD's recommendations require adequate drying of the groundnut pods. There is also the need for farmers to avoid storing the harvested nuts and pods in humid conditions. Furthermore, care should be taken to minimize mechanical or insect damage to the pods and nuts; such damages tend to promote the fungal growth that leads to aflatoxin contamination.

²³ These cultivars were developed by ICRISAT and CERAAS.

In 2002, research results were applied to pilot plots. The quality of produced groundnuts was monitored throughout the production and post-harvest stages in order to assess its compatibility with international market standards. Preliminary research results suggest that the program, if adopted, will increase significantly the output (and export) of high quality²⁴ confectionery groundnuts (Sagarra 2002a). A training module on the management of aflatoxin risk has also been developed and tested on groups of farmers, with the aim of sensitizing them to quality management issues.

In a nutshell, after two and a half years of research, CIRAD has made some modest contribution useful for the production and processing of confectionery groundnuts that meet the European Union's aflatoxin standards. There is the need however, to educate agricultural extension staff on issues pertaining to confectionery groundnut production, and to complete the accreditation process of the national aflatoxin laboratory (Sagarra 2002a).

2.5 Conclusion

The groundnut sector is of crucial importance to Senegal's economy. Due to natural, economic, and political factors, the sector has not been able to exert the desired impact on the economy. This failure of the groundnut sector to exert the desired impact is reflected in fluctuating production and export levels. With the global concern about the health hazards of aflatoxin contamination, many developed countries have imposed strict aflatoxin standards on groundnut imports. Of particular significance is the new EU harmonized (and more stringent) set of aflatoxin standards. Since Europe is a major destination for Senegal's confectionery groundnut exports, research into reducing aflatoxin contamination is critical.

²⁴ That is, conforming to the European Union's aflatoxin standards.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

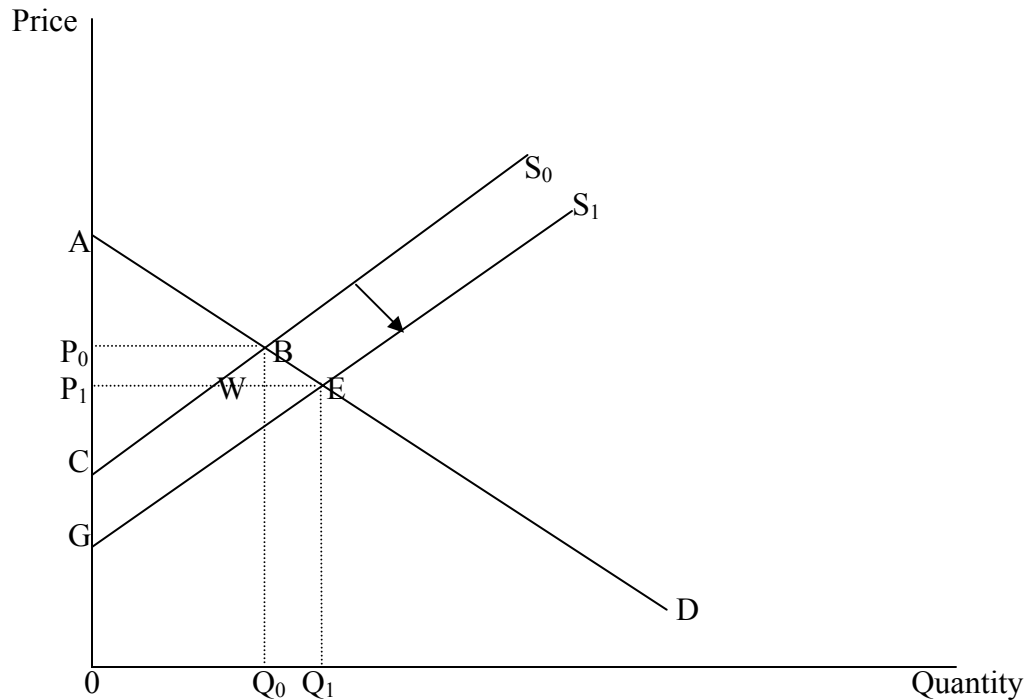
This study employs the economic surplus technique to project the economic impact of research into the development of an aflatoxin-reducing program in Senegal's confectionery groundnut sector. The choice of this approach is informed by its appropriateness for assessing the impact of agricultural research (Alston, Norton, and Pardey 1995, and Masters et. al. 1996). The discussion of the methodology employed in the study will be preceded by a review of conceptual issues, as well as, a survey of some empirical studies. The conceptual issues relate to the use of economic surplus measures in agricultural research evaluation, and the imposition of technical barriers to trade. The empirical studies to be reviewed are studies related to one or more of the above issues.

3.2 The Use of Economic Surplus Measures in Agricultural Research Evaluation

3.2.1 The Basic Model

The basic model of the distribution of economic surplus resulting from the adoption of cost-reducing technology is presented here. This model assumes, for illustrative purposes, the existence of a closed economy, and deals with a single homogeneous good. In Figure 3.1, line D represents the demand curve for the good, while lines S_0 and S_1 represent the "without research" and "with research" supply curves respectively. The adoption of research leads to a reduction in cost per unit of production leading to a rightward shift of the supply curve. The area of region ABC represents the "without research" economic surplus. The "without research" economic surplus is made up of the sum of consumer and producer surpluses, i.e., the sum of areas ABP_0 and P_0BC respectively. The "with research" economic surplus is also shown by the area of region AEG. The area of region AEG similarly consists of the sum of the corresponding consumer and producer surpluses, i.e. area AEP_1 plus area P_1EG . Thus, the gain in economic surplus is represented by area AEG less area ABC, which yields area BEGC.

Figure 3.1 **The Basic Economic Surplus Model**



It is often useful to think of the gain in economic surplus as the sum of a change in consumer surplus and a change in producer surplus. The gain in consumer surplus is easily determined as being equal to area P_0BEP_1 (i.e., area AEP_1 less area ABP_0). The change in producer surplus is however, less obvious. It is determined by area P_1EG less area P_0BC . But, area P_1WC is contained in each of areas P_1EG and P_0BC . Thus, the gain in producer surplus is area $CWEG$ less area P_0BWP_1 . The distribution of the change in economic surplus may therefore be summarized as follows:

$$\text{Change in consumer surplus } (\Delta CS) = \text{area } P_0BEP_1 = \text{area } P_0BWP_1 + \text{area } BEW$$

$$\text{Change in producer surplus } (\Delta PS) = \text{area } CWEG - \text{area } P_0BWP_1$$

$$\text{Change in economic (or total) surplus } (\Delta TS) = \text{area } BEW + \text{area } CWEG = \text{area } BEGC.$$

If we assume that the demand and supply curves are linear, and that the shift in the supply curve is parallel, then the changes in consumer surplus, producer surplus, and economic surplus can be computed as follows (Alston, Norton, and Pardey 1995):

$$\Delta CS = P_0Q_0Z (1+0.5Z\eta)$$

$$\Delta PS = P_0 Q_0 (K-Z) (1+0.5Z\eta)$$

$$\Delta TS = \Delta CS + \Delta PS = P_0 Q_0 K (1+0.5Z\eta)$$

Let the elasticity of supply be represented by ε . Then, in the above expressions, K is the vertical shift of the supply curve expressed as a proportion of the initial price; η is the absolute value of the elasticity of demand; and $Z = K\varepsilon/(\varepsilon + \eta)$ is the decrease in price, relative to the “without research” price, due to the shift in supply.

In practice, the determination of the change in economic surplus entails aggregating the discounted change in economic surplus for each period.

3.2.2 Some Conceptual Issues

The use of economic surplus measures in the evaluation of agricultural research benefits requires that close attention be paid to a number of issues, some of which are listed (and discussed) below²⁵:

- i) the “*with and without*” comparison versus the “*before and after*” comparison
- ii) the role of uncertainty in the analysis
- iii) flaws of economic surplus measures.

The economic surplus approach to impact assessment is often carried out in a comparative-static partial equilibrium framework (Alston, Norton, and Pardey 1995 and Mills and Kamau 1998). As stressed by Alston, Norton, and Pardey (1995) and Masters et. al. (1996), the main logic behind this kind of analysis is to compare a “*without research*” scenario with a “*with research*” situation. An understanding of this objective is crucial to the implementation of any credible impact assessment; it is all too easy to confuse the “*with and without*” evaluation with the “*before and after*” comparison. The tendency to confuse the two comparisons is especially high when the analyst is confronted with time-indexed data. Since conditions keep changing with time, it is misleading to employ a “*before and after*” approach in a comparative static analysis, unless non-research-induced changes have been appropriately controlled for (Alston, Norton, and Pardey 1995 and Masters et. al. 1996).

²⁵ For a comprehensive discussion of these and related issues, see Alston, Norton, and Pardey (1995), Mills (Ed.) (1998) and Masters et. al. (1996).

To state that uncertainty characterizes the impact of agricultural research is to state the obvious. Many of the variables and parameters required to compute the returns to agricultural research are uncertain. The time profile of the research is uncertain, and so are the research expenditure and success rate. Furthermore, since market parameters such as prices, income, and elasticities of demand and supply are uncertain, the economic benefits accruing to producers and consumers will also be uncertain. To account for these uncertainties requires information about the probability distributions of the relevant variables. This information may be obtained from published studies, or from personal interaction with some experts. Even though it may still be difficult to obtain the required information, some estimation or assumptions would be appropriate. In the words of Alston, Norton, and Pardey (1995, p.34), "... any estimation of the benefits from research inevitably involves some estimations of, or assumptions about, all of the relevant uncertain variables." For obvious reasons, the level of uncertainty associated with ex-ante studies is higher than that of ex-post evaluations, especially for adoption. Thus, in ex-ante studies, it is appropriate to capture the research's probability of success when computing the research benefits. In spite of the importance of incorporating uncertainty into agricultural research evaluations, many studies have treated the variables involved in the evaluation process as deterministic, thus failing to make the analysis realistic (Alston, Norton, and Pardey 1995). The failure of these studies to address this concern may be attributed to the difficulty in determining reasonable probability distributions for the relevant uncertain variables.

There is considerable support among economists for the use of economic surplus measures to assess the aggregate economic impact of agricultural research. It is nevertheless subject to several criticisms. Given market equilibrium price and quantity of P and Q , respectively, a consumer surplus may be defined, as the difference between the maximum amount of money consumers are willing to pay for the quantity Q and the amount PQ they actually pay. In other words, it is the excess of consumers' maximum willingness to pay, over the actual amount paid. Similarly, a producer surplus refers to the excess of total revenue (actually received by producers) over the minimum amount (of monetary payment) necessary to induce them to offer the goods for sale. Despite their

intuitive appeal, the consumer and producer surplus concepts have come under some criticism.

A major flaw of the consumer surplus measure is that, it is not always clearly defined. This ambiguity occurs when there is a simultaneous price-income change or when there are multiple price changes, since these lead to different outcomes depending on the order of the changes (Sadoulet and de Janvry 1995). Major alternatives to the consumer surplus measure are compensating and equivalent variations. Compensating and equivalent variations have been defined by Alston, Norton and Pardey (1995, p.44) as follows:

Compensating variation, CV, is the amount of additional money (income) that would leave the consumer in the initial welfare position if it were possible to buy any quantity of the commodity at the new price.

Equivalent variation, EV, is the amount of additional money (income) that would leave the consumer in the new welfare position if it were possible to buy any quantity of the commodity at the old price.

As noted by Sadoulet and de Janvry (1995), compensating and equivalent variations do not suffer from the path dependency deficiency. The absence of this deficiency is their major advantage over the consumer surplus measure. This advantage notwithstanding, the consumer surplus concept is widely used in empirical studies due mainly to the fact that, it is not characterized by computational difficulties, where as the compensating and equivalent variations are not operational. According to Sadoulet and de Janvry (1995), when there is a single price change, the consumer surplus is greater than compensating variation, but less than equivalent variation, and the consumer surplus can be a good approximation for either compensating variation or equivalent variation in cases where the income effects are small. The producer surplus is also considered to be a less accurate measure of welfare change, due to large income effects associated with input (or product) price changes (Alston, Norton, and Pardey 1995).

3.2.3 Some Empirical Studies

In a study of the Senegalese groundnut sector, Soufi (2001) employs an ex-ante economic surplus framework to evaluate the economic impact of research into La Fleur

11 (a drought tolerant groundnut variety) on Senegal's economy. The analysis is applied to an aggregated market scenario and a disaggregated market case. For the former scenario, Soufi uses a closed economy model to conduct a farm level analysis, under the assumption that farmers sell all unshelled groundnut output to SONACOS at the producer base price. In the disaggregated market scenario, the analysis is carried out separately for each La Fleur 11 market in the groundnut sector, using various modifications of the basic ex-ante economic surplus model. The modifications include a pivotal supply shift, and a parallel demand shift due to population and income changes.

For the aggregated scenario, Soufi finds that consumers (SONACOS) are the primary beneficiaries of research, with their benefits averaging 6 times that of producers (farmers). The average overall gain in net social welfare is, however, 16 percent of the sum of producer- and consumer-surpluses, since the government incurs a research-induced increase in cost equivalent to 84 percent of the gain to producers and consumers. For the disaggregated market, consumers (SONACOS) benefit 3 times more than producers (farmers) at the farm level, while at the SONACOS (i.e. export) level, only producers (SONACOS) benefit from research. On the whole, Soufi finds support for investment in research into the La Fleur 11 groundnut variety in Senegal.

The Australian wool industry is the focus of a study by Mullen and Alston (1990) aimed at analyzing the returns to the industry from investment in Research and Development (R&D). The study which was a report to the Wool Research and Development Council, aimed at evaluating and comparing the distribution of benefits accruing to woolgrowers, processing firms and final consumers from cost cuts arising from successful R&D at different stages in the production, processing and marketing of wool. The analysis was done from the perspective of a "world" wool top industry that employs Australian wool, wool from other countries, and inputs such as labor and capital. A market equilibrium model of the wool industry was used to compare the returns from R&D activities that reduced costs by one percent in wool production, wool processing and textile manufacturing. The method of analysis entailed estimating the changes in prices and quantities of wool top, Australian wool, wool from other countries, and processing inputs resulting from a 1 percent decrease in the cost of producing or

processing wool. A key aspect of the study had to do with a determination of values for the most important market parameters.

The study found that the returns from farm production R&D activities were at least twice the magnitude of those from off-farm R&D. For example, in order to yield the same return as a 1 percent decrease in farm costs, wool top processing costs have to fall by nearly 6 percent. The sensitivity of the study's findings to key market parameters was evaluated. Another result of the study was that the share of total benefits accruing to the Australian wool industry from the three types of R&D activities ranged between 24 percent and 58 percent. The study further observes that while Australian woolgrowers nominally pay the wool levy to finance R&D activities, they are able to pass on part of the burden of the levy to wool top processors and consumers, in a way akin to how the benefits of R&D are distributed. Significantly, the Australian industry bears 58 percent of the wool levy.

In a study of Peruvian agriculture, Norton, Ganoza, and Pomareda (1987) employed an ex-ante²⁶ economic surplus framework to analyze the potential benefits of agricultural research and extension (R&E). The study analyzed the benefits of research and extension for five commodities (rice, corn, wheat, potatoes, and beans). The authors explicitly evaluated the impact of demand shifts and government pricing policies on the benefits of research and extension. This evaluation was accomplished through various refinements of the basic ex-ante economic surplus model. The first model refinement dealt with the issue of home consumption of own-production. A vertical demand curve was used to capture the low price sensitivity associated with home consumption of own-production. In the second refinement, demand shift factors were incorporated in the model, while the third model modification captured the fact that Peru was importing some of the commodities for which new technologies were being developed. A final model refinement considered the case of commodities for which supply exceeded domestic demand at the world price.

An analysis of the distribution of economic benefits to producers and consumers of the five crops indicated that, for commodities traded internationally, producers receive

²⁶ In a strict sense, the study was partly ex-post, since some of the estimates were based on already-released technologies or on technologies for which experimental results were available.

a larger share. Potato and beans R&E however benefit consumers more than producers, since prices decline with an increase in supply to the domestic market. The distribution of benefits of R&E was also found to be sensitive to the price elasticity of demand, with higher elasticities favoring producers relative to consumers. Furthermore, while consumer benefits were unaffected by the nature of supply shifts (i.e., parallel or pivotal), producer gains were highly sensitive to the kind of supply shift. The study's projected rates of return to R&E in Peru point to large returns to public investment, while variations in R&E benefits across crops bring to the fore issues related to the allocation of research funds.

Instead of making the standard assumption of a single price wedge, Mills (1998) uses a quadratic programming spatial equilibrium model to analyze the potential impact of maize research in six regions of Kenya. The regions are low tropics, dry mid-altitude, moist mid-altitude, dry transitional, moist transitional, and high tropics. The model, which is ex-ante, allows for reversible trade flows among multiple regions. Using 1992-94 monthly retail maize price data for over 30 markets across Kenya, the study estimated the transactions costs associated with inter-zonal trade. Given that regional price variations are a reflection of transportation and other miscellaneous costs of moving maize between regions, Mills uses these differences to construct a transactions cost matrix for regional trade. The study simulates the impact of research and other factors on Kenya's maize markets over a thirty-year period.

The results of the study indicate significant movements in price and quantity under both with-research and without-research scenarios. Mills also finds a reversal in the relative magnitude of regional prices over the period. Using an annual real discount rate of 5 percent, research-induced changes in producer- and consumer-surpluses are estimated. The results, on the whole, reflect high returns to continued maize research in Kenya. Mills is quick to point out however, that research alone will be inadequate for maintaining Kenyan self-sufficiency in maize production, a goal that requires an additional productivity growth of 1.5 - 2 percent per annum in each of the six regions. A sensitivity analysis carried out by the study suggests a strong inverse relation between supply elasticity and each of producer and total benefits from research. Another finding of the study is that, fixed price wedge models significantly overestimate the effect of

world trade on market prices in major maize growing regions, as well as producers' share of research benefits. Finally, the study is also relevant to the debate over trade policy; it highlights the fact that, public investments in maize research can lessen producers' losses attributable to market liberalization.

3.3 Technical Barriers to Trade

3.3.1. Implementation of Sanitary and Phytosanitary (SPS) Regulations

Standards have for a long time, been generally considered a legitimate (and even desirable) means of facilitating production and exchange. In the recent past however, the application of standards by countries have been characterized by controversy in international trade circles. This controversy stems from the realization that there is considerable latitude for the abuse of standard setting, by employing it to restrict international trade and protect domestic industries. As noted by Zarrilli (1999), abuse of standard setting can take the form of

- (i) unjustified different requirements in different markets;
- (ii) unnecessary expensive or time-consuming tests; or
- (iii) duplicative conformity assessment procedures.

During the Uruguay Round of Multilateral trade negotiations, two agreements were established to address these concerns. These are

- (a) the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement); and
- (b) the WTO Agreement on Technical Barriers to Trade (the TBT Agreement).

According to the Global Trade Network (GTN), standards affect trade in at least, three ways. They help in the achievement of social or public goals. For example, health or safety standards may be established to regulate the production, sale, or importation of a good as a public health policy. They are also used to clearly define products, thus facilitating compatibility and usability. Finally, standard setting may be employed as a disguised tool for unfairly restricting trade. The SPS and TBT Agreements aim at regulating the first two functions, while minimizing the third.

Sanitary and phytosanitary regulations are measures implemented by countries to protect the health or life of humans, animals, and plants. These regulations are usually applied to food, agricultural, and health products. An example of an SPS measure is the European Union (EU) maximum allowable Aflatoxin levels applied to food and agricultural products. As suggested by Jensen (2002) and Otsuki, Wilson, and Sewadeh (2001a), harmonization of SPS standards is crucial to the success of the SPS Agreement. Thus, prior to the signing of the SPS Agreement, some efforts were made by international bodies to harmonize various SPS measures (Jensen 2002). One of these organizations is the Codex Alimentarius Commission (Codex) for food safety. Zarrilli (1999) notes that SPS measures may address the characteristics of final products, the production process, and how the products are stored or transported. SPS measures may take various forms, including inspections, conformity assessment certification, import bans, and quarantine requirements (Zarrilli 1999). In general, developing countries are considerably constrained in their ability to meet the SPS requirements of developed countries. According to Jensen (2002), the difficulties faced by developing countries in this respect include the following:

- (i) the production costs of meeting the requirements;
- (ii) the conformity costs of ensuring the requirements are met;
- (iii) access to adequate technical and scientific expertise;
- (iv) lack of uniformity in the regulations across countries;
- (v) the tendency for these regulations to be complicated and subject to frequent changes.

These obstacles naturally make it difficult for exporters from the developing world to abide by the SPS Agreement. It is worth noting that the constraints faced by developing countries — with respect to SPS measures and the SPS Agreement — is closely linked to their financial and resource constraints. Solutions proposed to deal with these problems include the following (DFID 2002):

- (i) regional co-operation amongst developing countries
- (ii) reform and/or the development of international institutions responsible for SPS issues

- (iii) greater sensitivity (on the part of developed countries) to the needs of developing countries when promulgating and applying SPS standards.

3.3.2 A Survey of Some Theoretical and Empirical Studies on Technical Barriers to Trade

The growing importance of technical trade barriers has been the focus of an increasing number of studies. Technical barriers to trade (TBT) are regulations or standards imposed by countries to restrict the imports of goods that fail to meet certain safety, health, quality, or environmental standards. A major rationale for the imposition of technical trade barriers is the correction of market inefficiencies arising from negative externalities of imports (Roberts, Josling, and Orden 1999). This rationale stems from the assumption that market incentives are inadequate for producing the efficient amount of a good such as, food safety or good health, and that consumers are willing to pay more (e.g., owing to higher prices of food imports subject to technical trade restriction) to obtain the efficient quantity of the desired good. Roberts, Josling, and Orden (1999, p.3) have defined technical trade barriers more formally as “regulations and standards governing the sale of products into national markets that have as their *prima facie* objective the correction of market inefficiencies stemming from externalities associated with the production, distribution, and consumption of these products.”

The welfare impact of technical trade barriers is a challenging and evolving area of research. There is thus, a dearth of literature on the quantitative impact of these technical barriers. In an attempt to facilitate the economic analysis of technical trade barriers in a systematic way, Roberts, Josling, and Orden (1999) have proposed a classification scheme, as well as, a modeling framework for assessing the trade effects of technical trade barriers. The classification criteria proposed are policy instrument, scope of measure, and regulatory goal. The paper’s modeling framework is based on a synthesis of models employed in a number of studies²⁷. Roberts, Josling, and Orden identify the following three separate, but combinable effects of technical trade barriers:

²⁷ The studies are Krissoff, Calvin, and Gray (1997), Sumner and Lee (1997), Orden and Romano (1996), Thilmany and Barrett (1997), and Paarlberg and Lee (1998).

- (i) the “*regulatory protection*” effect, i.e., the fact that a regulation yields some rents to domestic producers
- (ii) the “*supply-shift*” effect, i.e., a component that focuses on the impact of imports on the domestic supply and the costs of enforcing compliance, and
- (iii) the “*demand-shift*” effect, which refers to an increase in demand for the good resulting from consumers’ increased information about the product.

The above effects are illustrated by the authors in a comparative static, partial equilibrium framework. Roberts, Josling, and Orden further observe that, unlike standard trade barriers, technical trade barriers exert an impact on international trade, for the most part, indirectly through the additional cost of compliance. They provide guidelines for determining the distribution of costs of compliance. The paper’s hypothesized distribution of the costs of compliance is summarized in Table 3.1.

Table 3.1 Scope of Measure from Importer and Exporter Perspective

	Regulation imposed on one exporter (specific)	Regulation imposed on all exporters (universal)
Regulation imposed by one importer (specific)	Either can avoid compliance costs by selling to or buying from other markets. “Potential” rather than actual trade impediment.	Importer bears cost of compliance as this cost becomes built in to selling price by all exporters.
Regulation imposed by all importers (universal)	Targeted exporter bears cost of compliance as importers can choose to buy from other sources.	Importers and exporters share the cost of compliance as the world market price adjusts to the cost. Price to buyers goes up and to sellers goes down.

Source: Roberts, Josling, and Orden (1999)

In a more recent study, Otsuki, Wilson, and Sewadeh (2001b) employ an econometric model to estimate the effect of changes in Aflatoxin standards on trade flows of groundnut products, using data for 15 European countries (Switzerland being the only non-EU country) and 9 African countries for the period, 1989-1998. The groundnut products whose trade flows are examined in the study are edible groundnuts, groundnut oil, and groundnut seeds. The study estimates the elasticity of import quantity with

respect to aflatoxin standards to be 1.11, 0.2, and 1.065 for edible groundnuts, groundnuts for oilseeds, and groundnut oil, respectively. The paper's results suggest that a 10 percent decrease in the maximum allowable level of aflatoxin B1 will cause the exports of edible groundnuts to fall by 11 percent. The study asserts that the new European Union regulation on aflatoxins will result in a trade flow that is 63 percent lower than when the Codex Alimentarius international standards are followed.

In another study about the European Union's harmonization of aflatoxin standards, Otsuki, Wilson, and Sewadeh (2001a) examine the impact of sanitary and phytosanitary standards on food trade between Africa and Europe. Using regression analyses, the authors quantify the impact of the European Union's new harmonized Aflatoxin standard on exports from Africa. In examining the new standard, which is based on the "precautionary principle"²⁸, they analyze trade and regulatory survey data for fifteen European and nine African countries between 1989 and 1998. They first estimated the elasticity of the pre-EU harmonized aflatoxin standards on the value of trade flows from nine African countries to fifteen European countries. Their estimate suggested that cereals, dried fruits, and edible nuts are affected by Europe's Aflatoxin standards. They then perform simulations under (i) pre-EU harmonized standard (status quo), (ii) an international standard indicated by guidelines set by Codex, and (iii) the EU new harmonized standard. The study suggests that trade in cereals, edible nuts, and dried fruits are affected by Europe's Aflatoxin standards. For example, a 1 percent lower maximum allowable level of Aflatoxin contamination will decrease groundnut trade by 1.3 percent. The study's results suggest that the implementation of the new (and more stringent) EU Aflatoxin standards will impact adversely on African exports of cereals, dried fruits, and nuts to Europe. More specifically, the study suggests that, even though the new EU standard would decrease health risk by roughly 1.4 deaths per billion a year, it will result in a US\$ 670 million (or 64 percent) reduction in African exports, in contrast to a regulation based on an international standard suggested by Codex guidelines.

In an extension of Otsuki, Wilson, and Sewadeh (2001a), Wilson and Otsuki (2001) assess the impact on world food trade, of adopting international food safety

²⁸ The precautionary principle, as a framework for decision-making, recommends the imposition of regulatory action against safety, environmental, or health risks, even if scientific evidence of risk is unclear.

standards and harmonization of standards. The study examines the impact of Aflatoxin standards in 15 importing (4 developing) countries on exports from 31 (21 developing) countries. Using econometric and simulation techniques, the authors also explicitly examine how exports and imports vary under different regulatory situations. The results of the study suggest that by adopting a harmonized Aflatoxin B1 standard based on the Codex guidelines, the cereal and nut trade would gain US\$ 6.1 billion over the 1998 level. Thus, the paper endorses the conclusion of Otsuki, Wilson, and Sewadeh (2001a) that the implementation of Aflatoxin standards more stringent than that proposed by the Codex guidelines is likely to be detrimental to developing country exports. The analysis of Otsuki and Wilson further highlights the adverse trade impact of a fragmented food safety system. They therefore stress the need to minimize differences in food safety standards among trading partners. They also call for efforts to directly support developing countries to upgrade aflatoxin standards to international levels, and to provide vaccination against hepatitis B.

3.4 The Empirical Model

As noted earlier, the present study uses the economic surplus approach to assess the potential economic impact of research into the development of an aflatoxin-reducing program in Senegal's confectionery groundnut sector. The analyses will be confined to confectionery groundnuts, since aflatoxin contamination in Senegal's groundnut sector is mainly a problem for the confectionery groundnuts sub-sector. For example, with regards to the oil groundnuts sub-sector, major investments by SONACOS in their processing facilities have contributed to their ability to meet the EU import requirements for levels of aflatoxin contamination.

3.4.1 Some Assumptions

- i. There are two markets for Senegal's confectionery groundnuts — the export market and the domestic market.

This assumption is purely a reflection of reality. It is expected that confectionery groundnuts that meet importers' aflatoxin-regulatory standards will be exported, while the rest will be supplied to the domestic market. The

major destination for Senegal's confectionery groundnut exports is the European Union. On the domestic front, confectionery groundnuts are consumed in various forms, such as groundnut paste, peanut butter, and edible groundnut products. Warning and Key (2002) also suggest, that the domestic oil-groundnut market is a potential alternative outlet for confectionery groundnuts.

ii. The groundnuts sold in the two markets are not homogeneous.

Given the technical restrictions on Senegal's groundnut exports, and the higher export price (relative to the domestic price), this assumption is logical. To the extent that exported groundnuts are more profitable than those sold on the domestic market, it is expected that all confectionery groundnuts satisfying importers' aflatoxin-regulatory limits would be exported, while the residual would be sold on the domestic market. As a result, exported groundnuts would be largely homogeneous, and the residual (domestic) groundnuts would also be essentially identical. Consequently, even though the groundnuts sold in the two markets may appear identical, they would be, technically, heterogeneous.

iii. The demand curve facing Senegal's confectionery groundnut exports is perfectly elastic.

The justification for this assumption hinges on the fact that Senegal's confectionery groundnut exports do not affect the world market price; the share of Senegal's groundnut exports in the global groundnut market is very low.

iv. The demand curve for the domestic market is downward sloping.

This assumption implies that an increase in price leads to a reduction in quantity demanded, and a fall in price increases the quantity purchased. An assumption of a negatively sloped domestic demand for groundnuts is supported by empirical studies (e.g., Badiane and Kinteh 1994).

v. The supply curves for the two markets are upward sloping.

This is a standard assumption supported by various studies on agricultural markets and Senegal's groundnut sector. It is based on the fact that an increase

in the price of groundnuts will, all other things being equal, induce farmers to allocate more resources to the production of groundnuts. Similarly, a fall in the price of groundnuts will serve as a disincentive to farmers, leading to a reallocation of inputs away from groundnut production. An empirical support for a positively sloped groundnut supply curve for Senegal is provided by Akobundu (1998).

vi. The demand and supply functions are linear in the two markets.

This assumption eases the task of computing the geometric areas of economic surplus changes; it facilitates the use of basic algebra for the calculation. As noted by Alston, Norton, and Pardey (1995), since linear demand and supply curves are characterized by varying elasticities, it is important to be explicit about where any assumed elasticities apply.

Notwithstanding the criticisms of the use of linear supply and demand models within the economic surplus framework²⁹, it has been suggested (Alston and Wohlgenant 1990, cited in Alston, Norton, and Pardey 1995), that when a parallel supply shift is used, a linear supply model is a valid approximation regardless of the true functional form.

vii. The adoption of the aflatoxin-reducing program leads to a parallel downward shift in the supply curve for the export market.

It is implicitly assumed that the adoption of aflatoxin-reducing program would lead to a reduction in production cost per unit of confectionery groundnut exports. The program-induced reduction in cost per unit is linked to the price premium enjoyed by farmers from selling in the world market (through the private export marketing company, NOVASEN). With the adoption of the aflatoxin-reducing program, farmers can increase their output (and export) of high quality confectionery groundnuts. As a result, profits will increase due to the price premium derived from selling in the export market. Higher profits of farmers would eventually induce them to allocate more resources to confectionery groundnut production, resulting in a downward shift of the export supply curve. In other words, the incentives for adoption lie

²⁹ See Alston, Norton, and Pardey (1995) for a discussion of the criticisms.

in the price premium on export, the ability to increase sales, and the resulting reduction in cost per unit. Thus, the adoption of the program will lead to the groundnut export supply curve shifting downwards to the right.

An alternative way of analyzing the impact of the program adoption on the groundnut export supply curve is to consider the effect on the average export price of groundnuts. The adoption of the aflatoxin-reducing program, by reducing the quantity of rejected groundnuts, will increase the average export price for groundnuts. The increase in groundnut price will, in turn, serve as an incentive for Senegal to increase the production of confectionery groundnuts. Thus, at each potential price level, more groundnuts will be supplied to the export market, leading to a downward (rightward) shift of the groundnuts export supply curve. The assumption of the parallel nature of the supply shift implies that the reduction in cost-per-unit is of the same magnitude at all potential output levels. Equivalently, it implies that the program adoption results in an equal quantity-increase at each potential price level. As noted earlier, the assumption of a parallel shift in supply is complementary to the assumption of the existence of linear supply and demand curves (Alston and Wohlgenant 1990).

viii. The adoption of the aflatoxin-reducing program leads to a parallel upward shift in the domestic supply curve.

This assumption is a consequence of the assumption that all confectionery groundnuts supplied to the domestic market are aflatoxin-contaminated. With the adoption of the aflatoxin-reducing program, there will be a fall in the production of aflatoxin-contaminated groundnuts, leading to a reduction in the quantity of confectionery groundnuts supplied to the domestic market at each price level. It should be noted also that the adoption of the aflatoxin-reducing program would reduce the quantity of rejected groundnut “exports”, thus leading to an upward (leftward) shift of the domestic supply curve for confectionery groundnuts.

ix. The demand curves in the two markets are unaffected by the adoption of the aflatoxin-reducing program.

The implicit assumption here is that, the adoption of the aflatoxin-reducing program neither affects the preferences nor incomes of confectionery groundnuts consumers, and it also does not affect the prices of commodities related to confectionery groundnuts.

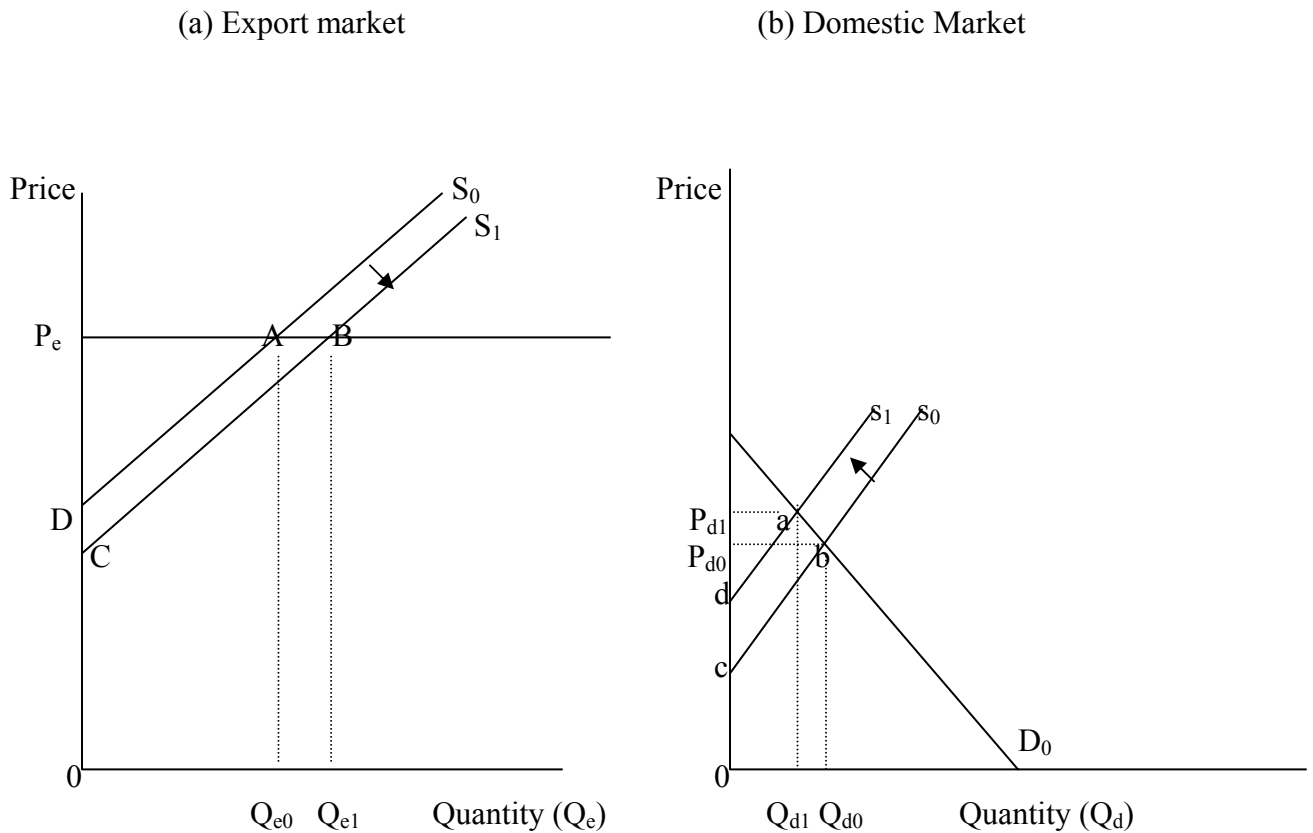
3.4.2 The Market Impact of Aflatoxin-Reducing Research

The market impact of aflatoxin-reducing research is illustrated in Figure 3.2. In the diagrams, Figure 3.2 (a) represents the export market, while the domestic market is shown in Figure 3.2 (b). The world market price for confectionery groundnuts is P_e . Since Senegal is a “small” country in the world market, it faces a perfectly elastic demand curve. Thus, changes in Senegal’s supply of groundnut exports will not alter the world price, while at the same time, any amount of groundnuts exported by Senegal can be sold at the ruling world market price. In the absence of program adoption, the quantity of Senegal’s exported (and accepted) confectionery groundnuts is Q_{e0} , while the amount sold and purchased on the domestic market is Q_{d0} ³⁰. The “without-program” domestic price for confectionery groundnuts is P_{d0} . As can be seen, P_{d0} is lower than P_e , which is partly a reflection of the superior quality of the exported confectionery groundnuts. With the adoption of the aflatoxin-reducing program, Senegal exports more confectionery groundnuts, leading to a shift of the export supply curve from S_0 to S_1 , and an increase in the quantity of confectionery groundnut exports from Q_{e0} to Q_{e1} . On the domestic front, the program adoption leads to a fall in supply from s_0 to s_1 . This fall in supply would, in turn, lead to a decrease in equilibrium quantity supplied (and demanded) from Q_{d0} to Q_{d1} , and an increase in equilibrium price from P_{d0} to P_{d1} . In the export market, the program adoption leads to an increase in economic surplus represented by the area of region ABCD. On the other hand, the program adoption leads to a decrease in the domestic market’s economic surplus; the area of region abcd shows the size of the reduction. In terms of changes in economic surplus, the impact of the adoption of the aflatoxin-

³⁰ This amount includes confectionery groundnuts that were not exported due to high aflatoxin levels, as well as, those that were “exported”, but were rejected by the importing country due to aflatoxin-contamination.

reducing program on Senegal's groundnut sector is the aggregate impact on the export and domestic markets.

Figure 3.2 The Markets for Senegal's Confectionery Groundnuts



3.4.3 The Determination of the Overall Change in Economic Surplus

Let W be the Aggregate Discounted Change in Total Economic Surplus.

Then,

$$W = \sum_{t \in z} [\Delta TS_t / (1+r)^t + \Delta ts_t / (1+r)^t]$$

Where:

ΔTS_t is change in total economic surplus, emanating from the export market, in period t ;

Δts_t is change in total economic surplus, emanating from the domestic market, in period t ;

z is the set of all the time periods within the duration of the research and adoption;

r is the discount rate;

$$\Delta TS_t = P_e Q_{e0} \mathbf{K}_t (1 + 0.5 \mathbf{K}_t \varepsilon)$$

$$\Delta ts_t = P_{d0} Q_{d0} \mathbf{V}_t (1 + 0.5 Z_t \eta)$$

\mathbf{K}_t is period t 's vertical shift of the export supply curve, expressed as a proportion of the initial price;

P_e : Equilibrium price in the export market.

Q_{e0} : Initial equilibrium quantity in the export market.

Q_{e1} : New equilibrium quantity in the export market.

ε is the price elasticity of supply in the export market.

\mathbf{V}_t is period t 's vertical shift of the domestic supply curve, expressed as a proportion of the initial price.

P_{d0} : Initial equilibrium price in the domestic market.

P_{d1} : New equilibrium price in the domestic market.

Q_{d0} : Initial equilibrium quantity in the domestic market.

Q_{d1} : New equilibrium quantity in the domestic market.

η is the absolute value of price elasticity of demand in the domestic market.

$Z_t = (\mathbf{V}_t \varepsilon) / (\varepsilon + \eta)$, where Z_t is the (domestic market's) change in price, relative to the initial value, due to the supply shift; and

e is the price elasticity of supply in the domestic market.

For the export market, let:

K be the expected program-induced percentage net quantity gain;

k_t be the program-induced total percentage change in quantity in period t .

\mathbf{k}_t be the program-induced vertical shift of the supply curve in period t .

A_t be the rate of program adoption in period t .

π be the probability of successful research.

Then, $k_t = \pi K A_t$, and

$$\mathbf{k}_t = (k_t P_e) / \varepsilon = (\pi K A_t P_e) / \varepsilon$$

$$\text{Thus, } \mathbf{K}_t = \mathbf{k}_t / P_e = (\pi K A_t P_e) / (P_e \varepsilon) = \pi K A_t / \varepsilon$$

For the domestic market, let:

V be the expected program-induced percentage net quantity gain;

v_t be the program-induced total percentage change in quantity in period t .

ν_t be the program-induced vertical shift of the supply curve in period t .

A_t be the rate of program adoption in period t .

π be the probability of successful research.

Then, $v_t = \pi V A_t$, and

$$\nu_t = (v_t P_{d0})/e = (\pi V A_t P_{d0})/e$$

Thus, $V_t = \nu_t/P_{d0} = (\pi V A_t P_{d0})/(P_{d0}e) = \pi V A_t/e$

3.5 Data Requirements and Some Derivations

The data for the analysis were obtained from various sources. These include the UN's Food and Agriculture Organization (FAO) database, the IMF's International Financial Statistics (IFS), and published studies. Even though CIRAD's aflatoxin research commenced in 2000, the period 1998-2000 is chosen as the base period, in order to reduce the influence of unusual years (Alston, Norton, and Pardey 1995). Thus, a base period value is the average for 1998-2000. It is worth noting also, that all monetary values are in real terms, with 1998-2000 being the reference period. After providing a general description of the different sets of data, the supply and demand functions underlying the model are derived. These derivations are followed by a discussion of the computational requirements for the "K_t-shift" parameters for the export and domestic sectors.

3.5.1 Prices

The export market price of confectionery groundnuts is derived from FAO data on the quantity and value of Senegal's groundnut exports. The base period quantity of Senegal's confectionery groundnut exports is 5167.67 metric tons, and the corresponding US dollar value is 2,748,333. The export price is therefore US\$531.83 per metric ton. It is important to note however, that the price received by farmers from selling their products on the export market (through NOVASEN) is much less. On the basis of a 1992-94 survey (Warning and Key 2002), the estimated base period price received by farmers (paid by NOVASEN) from selling on the export market is US\$276.35 per metric ton.

This price is nevertheless, higher than the producer price (US\$238.58 per metric ton) to be received if the output is sold on the domestic market. The farmers therefore derive a premium from selling on the export market (through NOVASEN).

The domestic market price of confectionery groundnuts is assumed to be equal to the groundnut producer price. Due to the export-oriented nature of the production of confectionery groundnuts, all output deemed suitable for export are purchased by NOVASEN. Groundnuts rejected by NOVASEN are expected to be sold on the domestic market, at a price roughly equal to the producer price of groundnuts. Thus, the base period domestic market price used in the simulation is US\$238.58 per metric ton, yielding a large price differential between the export and domestic markets.

3.5.2 Quantities

The quantity of confectionery groundnuts traded on the export market is obtained using FAO data on exports of raw shelled groundnuts³¹. As noted earlier, the three types of groundnuts cultivated in Senegal are oil groundnuts, seed groundnuts, and confectionery groundnuts. While oil groundnuts are destined for the oil extraction industry, seed groundnuts are usually marketed to farmers for replanting, and are not exported. Confectionery groundnuts on the other hand, are partly exported and partly processed into edible groundnut products and marketed locally. It is therefore reasonable to assume that confectionery groundnut exports are represented by the exports of raw groundnuts. Thus, the base period export quantity of confectionery groundnuts is 5167.67 metric tons. Since all contaminated confectionery groundnuts are assumed to be sold on the domestic market, the base period proportion of contaminated confectionery groundnuts is used to estimate the quantity sold on the domestic market. As explained below, the base year proportion of contaminated confectionery groundnuts is assumed to be 0.4, while the exported quantity has a share of 0.6³². Since the base period quantity of

³¹ Unshelled groundnuts are included in this data by converting them at 70 percent.

³² While Warning and Key (2002) suggest that as of the early 1990s, exports accounted for 80 percent of Senegal's confectionery groundnut sales, Otsuki et. al. (2001a, 2001b) and Dimanche (2001) suggest that, given the recent stricter aflatoxin standards by the EU, the corresponding figure for 2000 is considerably lower.

exported confectionery groundnuts is 5,167.67 metric tons, the corresponding quantity for the domestic sector is 3,445.11 metric tons.

It is important to note however, that the current production levels of Senegal's confectionery groundnut sector are extremely low. Significantly, one of the aims of the Senegalese government is to use CIRAD's research as a catalyst to accomplish a major growth of the sector. It is expected therefore, that the adoption of the aflatoxin-reducing program will be associated with a major output expansion. While the magnitude of the anticipated output growth is unknown, the extremely low current output levels make a tripling of production over a 25-year period a realistic expectation. In order to capture this anticipated growth in output, the base period quantities are tripled in the computation of the economic surplus changes.

3.5.3 Elasticities of Demand and Supply

The export market price elasticity of demand is infinitely large. This infinitely large value is due to the assumption that Senegal's groundnut exports constitute so small a fraction of the world groundnut market, that they are unable to influence the world market price. The supply elasticity for the export market (ε) is, on the other hand, assumed to be equal to 0.77, as estimated by Akobundu (1998) for Senegal's groundnuts. Thus, Senegal's exports of confectionery groundnuts are assumed to be inelastic. Given the numerous constraints facing Senegal's groundnut production and exports, the assumption of inelastic export supply is realistic. On the domestic front, the magnitude of the price elasticity of demand for confectionery groundnuts (η) is assumed to be 0.18, an estimate by Sullivan et al. (1992). Finally, as assumed for the export market, the domestic market's supply elasticity is assigned the value 0.77 (Akobundu 1998), since both markets have the same source of supply.

3.5.4 Program Adoption Profile

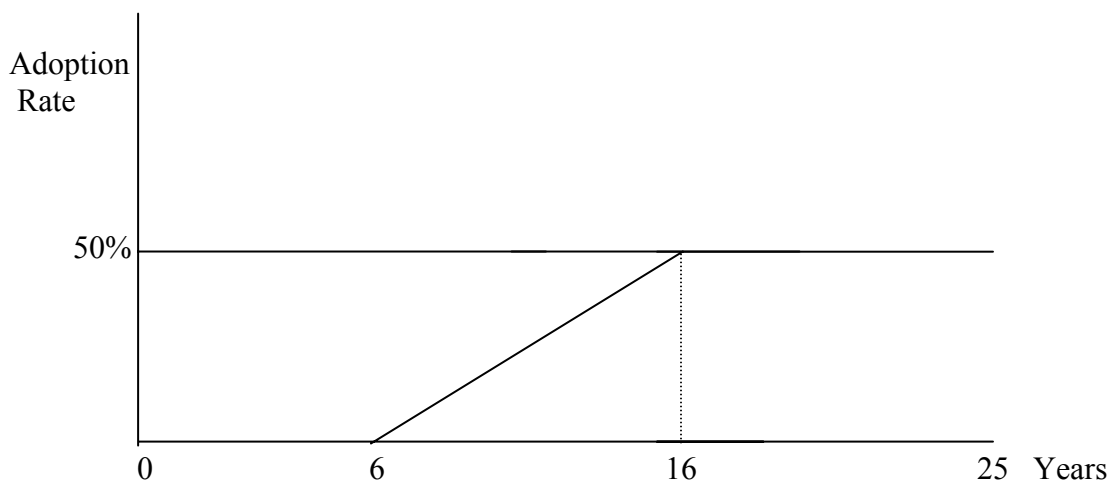
The analysis employs a 25-year linear program adoption profile. The actual functional form of the adoption profile may not be linear, but as noted by Alston, Norton, and Pardey (1995), a linear approximation has been widely used in empirical studies. For instance, in an evaluation of agricultural research in Senegal, Soufi (2001) employs a

linear approximation in profiling the adoption of a groundnut variety. The research and development lag for the present study is 6 years, since the expected duration of CIRAD's research and development is 6 years (Sagarra 2002a). It is also assumed that a 50 percent maximum adoption rate would be achieved after 10 years of adoption. This is an assumption guided by the rates used by Soufi (2001) and the following factors:

- i) Due to socio-cultural and other factors, maximum adoption rates in developing countries can be very low
- ii) Relative to selling on the domestic market, selling (through NOVASEN) on the export market is more profitable for farmers
- iii) The program being developed is expected to increase the output of high quality confectionery groundnuts
- iv) NOVASEN's monitoring of farming practices would enhance the adoption of the aflatoxin-reducing program.

Thus, the adoption rate (for the initial adoption phase) is 5 percent per year. It is worth noting also, that the adoption profile does not exhibit a disadoption phase; during the 25-year period, it is assumed that the aflatoxin-reducing program would not become obsolete. The adoption profile is summarized in Figure 3.3.

Figure 3.3 **The Program Adoption Profile**



3.5.5 Discount Factor

The computation of the Net Present Value (NPV) of the aflatoxin-reducing research requires that the projected future stream of net-benefits be discounted. In order to discount this stream of net benefits, it is necessary to decide on the choice of a discount factor, which in turn, depends on the rate of return to the projected cash flow. Even though the interest rate appears to be a natural choice for the determination of the discount factor, various interest rates exist in an economy, posing a problem as to which of the rates to use. The different kinds of interest rate include the Bank Rate (also known as Discount Rate), the Money Market Rate, the Treasury Bill Rate, the Deposit Rate, and the Lending Rate. The Bank Rate is the rate at which the central bank lends to commercial banks. This Rate, to a large extent, influences the rate at which commercial banks lend to the public. The Money Market Rate refers to the rate on short-term lending between financial institutions, while the Treasury Bill Rate is the rate applicable to short-term securities (IMF, 2001). The Deposit Rate on the other hand, usually refers to the rate offered by commercial banks to resident clients for demand, time, or savings deposits (IMF 2001). Finally, the Lending Rate is the rate applied to short- and medium-term loans by commercial banks to the private sector.

In the absence of data on the interest rate applied to loans for agricultural research in Senegal, this study employs the real lending rate to compute the discount factor. Two considerations informed the choice of the real lending rate. First, the (nominal) lending rate is a reasonably good proxy for the interest rate applied to loans for agricultural research. Second, it is important to capture inflationary influences in the discounting of the future stream of net-benefits, since the value of money tends to fall with time. The real interest rate used for the discounting is obtained as follows:

$$\text{Real interest rate} = \text{Nominal lending rate} - \text{Inflation rate} = 8.9\% - 1.9\% = 7\%$$

3.5.6 Research Cost

The cost of CIRAD's research includes expenditures on equipment, experiments, and salaries of researchers and other project employees. The cost of the first half of the project is expected to be considerably more than that of the second half, due to

expenditure on heavy equipment in the first half. The estimated total research cost is summarized in Table 3.2. The present value of the estimated cost is US\$545,527.99.

Table 3.2 Research Cost

Year	Research Cost (US\$)
2000	183,099.3
2001	176,105.0
2002	186,072.37
2003	32,732.11
2004	31,847.95
2005	31,547.49

Source: Calculated from information obtained from Sagarra (2002a).

3.5.7 Probability of Successful Research

Clearly, the issue of whether CIRAD’s aflatoxin research will result in an effective aflatoxin-reducing program is uncertain. Obtaining the probability of the research’s success is, however, not easy. Nevertheless, progress made so far on the project (Sagarra 2002b) suggests there is a high chance of success. As a result, the “probability of successful research” parameter (π) used for the present study is 0.8. Table 3.3 shows values of the parameters used for the estimation of economic surplus changes.

Table 3.3 **Parameter Values for the Computation of Economic Surplus Changes**

Parameter Description	Value of Parameter
Base period export price (P_e) (US\$/MT)	531.83
Base period domestic price (P_{d0}) (US\$/MT)	238.58
Base period export quantity (Q_{e0}) (MT)	5,167.67
Base period domestic quantity (Q_{d0}) (MT)	3,445.11
Price elasticity of supply in export market (ϵ)	0.77
Price elasticity of supply in domestic market (e)	0.77
Absolute value of price elasticity of demand in domestic market (η)	0.18
Discount rate (r)	7%
Probability of successful research (π)	0.8

3.5.8 Derivation of Supply and Demand Functions

(i) Derivation of the Domestic Market's Supply and Demand Functions

The domestic market supply function may be expressed as:

$$Q_{d0} = a + bP_{d0}, \text{ where } a > 0 \text{ and } b > 0$$

The price elasticity of supply is given by:

$$e = b (P_{d0}) / (Q_{d0}) = 0.77$$

$$\Rightarrow b = 0.77(Q_{d0}) / (P_{d0})$$

But, $P_{d0} = 238.58$ and $Q_{d0} = 3,445.11$

Thus, $b = (0.77) (3,445.11) / (238.58) = 11.12$

Also, from the supply function,

$$a = Q_{d0} - bP_{d0} = 3,445.11 - (11.12) (238.58) = 792.1$$

Thus, the domestic market supply function is expressed as follows:

$$Q_{d0} = 792.1 + 11.12P_{d0}$$

The domestic market demand function may be expressed as:

$$Q_{d0} = c - dP_{d0}, \text{ where } c > 0 \text{ and } d > 0.$$

The absolute value of the price elasticity of demand is given by:

$$\eta = d(P_{d0})/Q_{d0} = 0.18$$

$$\Rightarrow d = 0.18 (Q_{d0}) / (P_{d0})$$

$$\text{But, } P_{d0} = 238.58 \text{ and } Q_{d0} = 3,445.11$$

$$\text{Thus, } d = (0.18) (3,445.11) / (238.58) = 2.6$$

Also, from the demand function,

$$c = Q_{d0} + dP_{d0} = 3,445.11 + (2.6) (238.58) = 4,065.42$$

Thus, the domestic market demand function is expressed as:

$$Q_{d0} = 4,065.42 - 2.6P_{d0}$$

(ii) Derivation of the Export market's Supply and Demand Functions

The export supply function may be expressed as:

$$Q_{e0} = A + B P_e, \text{ where } A > 0 \text{ and } B > 0.$$

The price elasticity of supply is given by:

$$\varepsilon = B P_e / Q_{e0} = 0.77$$

$$\Rightarrow B = 0.77 Q_{e0} / P_e$$

$$\text{But, } P_e = 531.83 \text{ and } Q_{e0} = 5167.67$$

$$\text{Thus, } B = (0.77) (5167.67) / (531.83) = 7.48$$

Also, from the supply function,

$$A = Q_{e0} - B P_e = 5167.67 - (7.48) (531.83) = 1,189.58$$

Thus, the export supply function is expressed as: $Q_{e0} = 1,189.58 + 7.48P_e$

The export demand function is: $P_e = 531.83$

3.5.9 Computational Requirements for the “ K_t – Shift” Parameters

A key to obtaining the “ K_t – shift” parameters is the estimation of the expected net quantity gain (%) from aflatoxin-reducing research. The framework for computing the expected net quantity gain (K , for the export sector and V , for the domestic sector) is presented below:

Assumptions:

1. The adoption of aflatoxin-reducing program does not lead to a change in farm yield.
2. The average farm yield (MT/ha) is given by A .
3. The “without program” cost of production is given by c .

4. The “with program” cost of production is represented by C.
5. The “without program” proportion (b) of non-contaminated groundnuts is less than the “with program” proportion (B).
6. The proportion of contaminated groundnuts and the proportion of non-contaminated groundnuts sum up to one.

Table 3.4 summarizes, for the export and domestic sectors, the method for obtaining the expected percentage net-revenue gain (which is equivalent to the expected percentage net quantity gain).

Table 3.4 Derivation of Expected Net-Revenue Gain

	Without Program		With Program	
	Exports	Domestic	Exports	Domestic
Share	b	1-b	B	1-B
Price	P_e	P_d	P_e	P_d
Quantity	Ab	$A(1-b)$	AB	$A(1-B)$
Gross Revenue	AbP_e	$A(1-b)P_d$	ABP_e	$A(1-B)P_d$
Costs	bc	$(1-b)c$	BC	$(1-B)C$
Net Revenue (NR)	$b(AP_e - c)$	$(1-b)(AP_d - c)$	$B(AP_e - C)$	$(1-B)(AP_d - C)$
		Export Sector	Domestic Sector	
Program-Induced Change in Net-Revenue (ΔNR)		$B(AP_e - C) - b(AP_e - c)$	$(1-B)(AP_d - C) - (1-b)(AP_d - c)$	
Net-Revenue Gain (%)		$100(\Delta NR)/NR$	$100(\Delta NR)/NR$	

After computing the expected net quantity gains from aflatoxin-reducing research, the “ K_t – shift” parameters are derived as outlined in subsection 3.4.3. Thus for the export

sector, the “ K_t – shift” parameter is given by $K_t = \pi K A_t / \varepsilon$, while for the domestic sector, it is given by $V_t = \pi V A_t / e$, where π is the probability of successful research, K is the export sector’s percentage net quantity gain, V is the domestic sector’s percentage net quantity gain, A_t is the period-specific adoption rate, ε is the export supply elasticity, and e is the domestic market’s supply elasticity.

3.5.10 Program-Induced Percentage Net Quantity Gains Under Different Scenarios of Program-Effectiveness

Different assumptions about the effectiveness of the aflatoxin-reducing program lead to different program-induced percentage net quantity gains. The index of program-effectiveness used in this study, is the program-induced percentage increase in high quality³³ groundnuts.

There is a dearth of data about levels of aflatoxin contamination in Senegal’s confectionery groundnut sector. Information gleaned from various sources however, suggest that a value of 40 percent for the “without-program” proportion of aflatoxin-contaminated groundnuts (i.e., an export share of 60 percent) is realistic³⁴. CIRAD’s research has not firmly established the expected level of program-effectiveness. Preliminary research results suggest however, that if adopted, the aflatoxin-reducing program will be significantly effective. As a result, the scenarios of program-effectiveness explored in this study are 30%, 40%, 50%, and 60% program-induced increases in high quality groundnuts. These scenarios of program-effectiveness are equivalent to “with-program” export shares of 78%, 84%, 90%, and 96%, respectively. Table 3.5 shows values of the parameters used to estimate the program-induced percentage net-quantity changes under various scenarios of program-effectiveness. In Table 3.6, a breakdown of the “without program” and “with program” costs are shown. Table 3.7 shows the percentage net-quantity gains under the various scenarios.

³³ That is, conforming to the European Union’s aflatoxin standards.

³⁴ As noted earlier, Warning and Key (2002) suggest that as of the early 1990s, exports accounted for 80 percent of Senegal’s confectionery groundnut sales. Otsuki et. al. (2001a, 2001b) and Dimanche (2001) however, suggest that given the recent stricter aflatoxin standards by the EU, the corresponding figure for the base period is considerably lower.

**Table 3.5 Parameter Values for the Estimation of Percentage Net Quantity Gains
Under Various Levels of Program-Effectiveness**

Parameter	Value
Farm Yield (MT/ha)	1.123
“Without-Program” Production Cost (US\$) per Hectare (c)	65.94
“With-Program” Production Cost (US\$) per Hectare (C)	85.06
“Export market” Price ³⁵ (US\$/MT)	276.35
Domestic Market Price (US\$/MT)	238.58
“Without-Program” share (b) of exports	0.6
“With-Program” share (B) of exports	Dependent on Program-Effectiveness

Sources: Obtained (or calculated using data) from Warning and Key (2002), Economist Intelligence Unit (2002), IMF’s International Financial Statistics, 2001 Year Book, Trade Point Senegal (2002), and Sagarra (2002b).

**Table 3.6 Estimated “Without-Program” and “With-Program” Costs of
Production**

Item/Activity	Without-Program Cost (US\$)/ha	With-Program Cost (US\$)/ha
Seed	27.83	33.34
Granox treatment	1.55	1.55
Sowing	9.14	9.13
Manure	13.71	13.68
Fungicide treatment	0	13.68
Harvest and post-harvest activities	13.71	13.68
Total	65.94	85.06

Source: Estimated using information from Warning and Key (2002) and Sagarra (2002b).

³⁵ This refers to the price received by farmers from NOVASEN (the private export marketing company). With NOVASEN playing an intermediary role, the relevant “export price” for the computation is the price received by farmers from NOVASEN. The actual base period world market price is US\$531.83.

Table 3.7 Percentage Net-Quantity Gains Under Different Scenarios

	“Without-Program” Export Share/ “With-Program” Export Share	Net Percentage Change in Export Quantity	Net Percentage Change in Domestic Quantity
Scenario One (30% increase in high quality groundnuts)	0.6/0.78	19.83	-50.21
Scenario Two (40% increase in high quality groundnuts)	0.6/0.84	29.05	-63.79
Scenario Three (50% increase in high quality groundnuts)	0.6/0.9	38.26	-77.37
Scenario Four (60% increase in high quality groundnuts)	0.6/0.96	47.48	-90.95

CHAPTER FOUR: RESULTS

4.1 Introduction

In this chapter, the results of the data analysis are presented and discussed. The results represent simulations of economic surplus changes under different assumptions about program-effectiveness. For each scenario, the overall net-gain to Senegal's economy is obtained by subtracting the present value of the estimated research cost from the present value of the aggregate change in economic surplus. It should be noted that the analysis does not take into account the possible health benefits of the research. These health benefits are expected to result if the research leads to a decline in the consumption of aflatoxin-contaminated groundnuts. In spite of the fact that these health effects are important, explicitly accommodating them in the present study would have been too ambitious. Consequently, even though the results do not include the impact on health, the discussion of the results takes due cognizance of the possible health benefits.

4.2 Presentation of Results

4.2.1 Scenario One: A 30% Increase in High Quality Groundnuts

The results for this scenario are shown in Table 4.1. In the export sector, there is a zero net-gain for consumers. Thus, all the gains (US\$3,966,114) accrue to producers. The domestic sector incurs a loss of US\$2,862,568, with most (US\$2,320,187) of it borne by consumers. In the aggregate, in spite of a loss of US\$2.32 million to consumers, there is an overall net-gain of US\$558,018 to the economy.

Table 4.1 Economic Surplus Changes and Overall Net-Gain for Scenario One

	Export sector	Domestic Sector	Combined Sectors
NPV of Changes in Consumer Surplus (US\$)	0	-2,320,186.75	-2,320,186.75
NPV of Changes in Producer Surplus (US\$)	3,966,113.64	-542,381.32	3,423,732.33
NPV of Changes in Total Surplus (US\$)	3,966,113.64	-2,862,568.06	1,103,545.58
Overall Net-Gain (US\$): 1,103,545.58 - 545,527.99 = 558,017.59			

Given the significant role played by NOVASEN in the marketing of Senegal's confectionery groundnut exports, it is useful to think of producers as consisting of farmers and NOVASEN. Thus, in the export sector, the gains earned by producers are shared between the farmers and NOVASEN. On the basis of a 1992-94 survey (Warning and Key 2002), the shares of farmers and NOVASEN in the surplus gain are estimated to be 46 percent and 54 percent respectively. The distribution of the aggregate research-induced producer net-gain is shown in Table 4.2. From the export sector, farmers and NOVASEN gain US\$1,824,412 and US\$2,141,701 respectively. With farmers losing US\$542,381 from production for the domestic market, their net-gain is US\$1,282,033; this is 37.4 percent of the aggregate producer net-gain. NOVASEN's total net-gain of US\$2,141,701 accounts for the remaining 62.6 percent.

Table 4.2 Distribution of Producer Gains for Scenario One

	Farmers	NOVASEN	All Producers
Export sector Gains (US\$)	1,824,412.28	2,141,701.37	3,966,113.65
Domestic Sector Gains (US\$)	-542,381.32	0	-542,381.32
Net-Gain (US\$)	1,282,032.96	2,141,701.37	3,423,732.33

4.2.2 Scenario Two: A 40% Increase in High Quality Groundnuts

In this scenario, there is a net-gain of US\$5,895,729 to Senegal’s export sector, with all the gains accruing to producers. The export sector’s economic surplus changes do not affect consumers. In the domestic sector, there is a total loss of US\$3,621,109, with consumers bearing US\$2,935,004 of the loss and producers accounting for the remainder. The aggregate change in economic surplus is US\$2,274,620, and the overall net-gain to the Senegalese economy is US\$1,729,092. These changes in economic surplus and the overall net-gain are shown in Table 4.3.

Table 4.3 Economic Surplus Changes and Overall Net-Gain for Scenario Two

	Export sector	Domestic Sector	Combined Sectors
NPV of Changes in Consumer Surplus (US\$)	0	-2,935,003.95	-2,935,003.95
NPV of Changes in Producer Surplus (US\$)	5,895,728.50	-686,104.82	5,209,623.68
NPV of Changes in Total Surplus (US\$)	5,895,728.50	-3,621,108.77	2,274,619.73
Overall Net-Gain (US\$): $2,274,619.73 - 545,527.99 = 1,729,091.74$			

The aggregate research-induced net-gain to producers is distributed between farmers and NOVASEN as summarized in Table 4.4. The export sector yields a gain of US\$2,712,035 to farmers, while NOVASEN earns a gain of US\$3,183,693. Since NOVASEN’s net-gain from the domestic sector is zero, the total surplus gain accruing to NOVASEN is US\$3,183,693. Farmers on the other hand, incur a domestic sector loss of US\$686,105 due to the research-induced decline in sales to the sector. As a result, the aggregate research-induced net-gain to farmers is US\$2,025,930. Thus, in the aggregate, the research-induced net-gain in producer surplus is US\$5,209,624, with farmers accounting for 38.9 percent and NOVASEN receiving the remaining 61.1 percent.

Table 4.4 Distribution of Producer Gains for Scenario Two

	Farmers	NOVASEN	All Producers
Export Sector Gains (US\$)	2,712,035.11	3,183,693.39	5,895,728.50
Domestic Sector Gains (US\$)	-686,104.82	0	-686,104.82
Net-Gain (US\$)	2,025,930.29	3,183,693.39	5,209,623.68

4.2.3 Scenario Three: A 50% Increase in High Quality Groundnuts

In this third situation, the export sector gives producers a gain of US\$7,877,474. Since consumers reap a zero net-gain, the total surplus gained from the export sector is US\$7,877,474. The domestic sector, however, incurs a loss of US\$4,372,973, with consumers bearing more than 80 percent of this loss (see Table 4.5). Under this scenario, the aggregate impact of aflatoxin-reducing research on the Senegalese economy is a gain of US\$7,048,911 to producers, and a loss of US\$3,544,410 to consumers, yielding an aggregate change in economic surplus of US\$3,504,501. With the research cost being US\$545,528, the overall net-gain to Senegal's economy is US\$2,958,973.

Table 4.5 Economic Surplus Changes and Overall Net-Gain for Scenario Three

	Export sector	Domestic Sector	Combined Sectors
NPV of Changes in Consumer Surplus (US\$)	0	-3,544,409.63	-3,544,409.63
NPV of Changes in Producer Surplus (US\$)	7,877,474.17	-828,563.29	7,048,910.88
NPV of Changes in Total Surplus (US\$)	7,877,474.17	-4,372,972.92	3,504,501.25
Overall Net-Gain (US\$): $3,504,501.25 - 545,527.99 = 2,958,973.26$			

In terms of the distribution of producer surplus, out of the US\$7,877,474 gained by producers from the export sector, farmers earn US\$3,623,638, and NOVASEN receives US\$4,253,836. Given NOVASEN's zero net-gain from the domestic sector, its

aggregate research-induced net-gain is US\$4,253,836. As shown in Table 4.6, farmers lose US\$828,563 from the domestic sector, leaving them with an aggregate net-gain of US\$2,795,075. Since in the aggregate, producers' research-induced net-gain is US\$7,048,911, farmers get a share of 39.7 percent, while NOVASEN receives the remaining 60.3 percent.

Table 4.6 Distribution of Producer Gains for Scenario Three

	Farmers	NOVASEN	All Producers
Export sector Gains (US\$)	3,623,638.12	4,253,836.05	7,877,474.17
Domestic Sector Gains (US\$)	-828,563.29	0	-828,563.29
Net-gain (US\$)	2,795,074.83	4,253,836.05	7,048,910.88

4.2.4 Scenario Four: A 60% Increase in High Quality Groundnuts

The results for this scenario are depicted in Table 4.7. In this case, the export sector yields an economic surplus gain of US\$9,915,654 to producers, while consumers are unaffected. Thus, the total net-gain from the export sector is approximately US\$9.92 million. The domestic sector, on the other hand, incurs a loss of US\$5,118,161. Of this loss, consumers bear US\$4,148,404, while producers account for the remainder. Combining the changes in the two sectors results in an aggregate gain of US\$8,945,897 to producers and a loss of US\$4,148,404 to consumers, leading to an aggregate change in economic surplus of US\$4,797,494. The overall net-gain for the economy is US\$4,251,966.

Table 4.7 Economic Surplus Changes and Overall Net-Gain for Scenario Four

	Export sector	Domestic Sector	Combined Sectors
NPV of Changes in Consumer Surplus (US\$)	0	-4,148,403.78	-4,148,403.78
NPV of Changes in Producer Surplus (US\$)	9,915,654.12	-969,756.73	8,945,897.39
NPV of Changes in Total Surplus (US\$)	9,915,654.12	-5,118,160.51	4,797,493.60
Overall Net-Gain (US\$): 4,797,493.60 - 545,527.99 = 4,251,965.61			

The distribution of the producer surplus, once again, reflects a higher net-gain for NOVASEN, relative to what farmers receive. From the export sector, NOVASEN earns a surplus of US\$5,354,453, while farmers obtain US\$3,591,444. Farmers, however, incur a loss of US\$969,757 from the domestic sector, while NOVASEN is unaffected by the decrease in the domestic market sales. In the aggregate, the research-induced net-gains accruing to farmers and NOVASEN are US\$3,591,444 and US\$5,354,453, respectively. Thus, of the US\$8.95 million aggregate producer net-gain (see Table 4.8), NOVASEN takes a share of 59.9 percent, while the remaining 40.1 percent accrues to farmers.

Table 4.8 Distribution of Producer Gains for Scenario Four

	Farmers	NOVASEN	All Producers
Export sector Gains (US\$)	4,561,200.89	5,354,453.22	9,915,654.11
Domestic Sector Gains (US\$)	-969,756.73	0	-969,756.73
Net-gain (US\$)	3,591,444.16	5,354,453.22	8,945,897.38

4.3 Discussion of Results

The results of the analysis validate the hypotheses of the study. It would be recalled that the hypotheses were stated as follows:

- (i) The adoption of CIRAD's aflatoxin-reducing program would enhance the welfare of Senegal's confectionery groundnut farmers.
- (ii) An overall welfare net-gain would be derived by Senegal from the adoption of the program.

With regard to the first hypothesis, results for all scenarios suggest that Senegal's confectionery groundnut farmers will enjoy an overall net-gain from the adoption of the aflatoxin-reducing program. The results also suggest a positive relationship between program-effectiveness and farmers' net-gain. For example, for the lowest program-effectiveness considered (i.e., scenario one) the net-gain to farmers is US\$1.28 million, while for the highest program-effectiveness (i.e., scenario four), farmers reap a net-gain of US\$3.59 million. Farmers' net-gain for scenarios two and three are US\$2.03 million and US\$2.8 million, respectively. Thus, while the results strongly suggest that farmers' welfare will be enhanced by the adoption of the aflatoxin-reducing program, there is evidence to suggest a positive relationship between program-effectiveness and farmers' net-gain.

The validity of the second hypothesis has also been established; all the scenarios register positive overall net-gains for Senegal's economy. It must be noted though, that the overall net-gains are very small. The low overall net-gains might be explained by the fact that the analysis did not cover every aspect of CIRAD's overall aflatoxin project. The results are also suggestive of a positive relationship between program-effectiveness and the overall net-gain to Senegal's economy. For instance, in the least optimistic case (i.e., scenario one), there is an overall net-gain of US\$0.56 million, while the most optimistic scenario (i.e., scenario four) yields an overall net-gain of US\$4.25 million. The corresponding figures for scenarios two and three are US\$1.73 million and US\$2.96 million, respectively.

The results of the analysis also suggest, that in the aggregate, only consumers will incur a loss³⁶ as a result of the adoption of the aflatoxin-reducing program. This outcome stems from the fact that while changes in the export sector leave Senegalese consumers unaffected, the fall in domestic sales of confectionery groundnuts leads to a reduction in

³⁶ In reality, consumers may not lose if the potential health gains from the decreased consumption of aflatoxin-contaminated groundnuts are taken into account.

consumer surplus. It is crucial to note however, that confectionery groundnuts sold in the domestic market are assumed to be contaminated with aflatoxin. An implication of this assumption is that, if the aflatoxin-reducing program results in a decreased consumption of groundnuts by residents of Senegal, the health benefits of the reduced consumption could well outweigh any perceived economic loss. On the other hand, a program-induced increase in the domestic consumption of contaminated confectionery groundnuts (due to output growth) cannot be ruled out. Since the economic evaluation of the health impact of CIRAD's aflatoxin-reducing research falls outside the scope of this study, the reported magnitude of loss to consumers should be treated with circumspection.

The distribution of producer surplus has also been highlighted in the analysis. Clearly, NOVASEN enjoys an edge over farmers in the distribution of the research-induced producer surplus. The results show however, that, as the index of program-effectiveness increases, farmers' share of aggregate net-gain rises slightly. For instance, in scenario one (where the index of program-effectiveness is lowest), farmers' share of the aggregate producer net-gain is 37.4 percent. The corresponding shares for scenarios two, three, and four, are 38.9 percent, 39.7 percent, and 40.1 percent, respectively. These numbers suggest that, even though groundnut farmers' share of aggregate producer net-gain might increase with a boost in program-effectiveness, NOVASEN would still capture the bulk of the gain in producer surplus. The leverage enjoyed by NOVASEN in Senegal's confectionery groundnut sector is linked to its fairly high monopsonistic power. So long as NOVASEN continues to supply a wide range of inputs to confectionery groundnut farmers on credit (in exchange for purchasing privileges), the farmers are likely to receive a lower share of aggregate producer net-gains.

4.4 Conclusion

Three main issues are captured by the results of the analysis. The major result is the strong indication, that a considerable potential exists for modest gains to be derived from aflatoxin-reducing research in Senegal's confectionery groundnut sector. This conclusion is strengthened by the fact that the results are obtained in the absence of an economic evaluation of the health impact of aflatoxin-reducing research. Secondly, the higher the effectiveness of the aflatoxin-reducing program, the higher the economic gains

are likely to be. Finally, Senegal's confectionery groundnut farmers are likely to continue to earn a lower share of research-induced producer net-gains, so long as NOVASEN enjoys some monopoly in the purchase of confectionery groundnuts.

CHAPTER FIVE: SUMMARY AND RECOMMENDATIONS

5.1 Summary

Attempts to safeguard the health of humans, animals, and plants, have led to the imposition of sanitary and phytosanitary standards (SPS) in respect of trade in agricultural products. One such product is groundnuts, a product whose cultivation and storage is prone to aflatoxin contamination. The health risks posed by aflatoxin contamination have been widely documented. These risks include severe necrosis, cirrhosis, and carcinoma of the liver. The seriousness of these potential health hazards have led to the imposition of more stringent aflatoxin-regulatory standards by many developed countries, notably, those in the EU. For groundnut exporters in the developing world, these standards pose a major challenge. Consequently, in Senegal's confectionery groundnut sector, research is being conducted into the development of an aflatoxin-reducing program. The present study has undertaken an ex-ante economic surplus evaluation of this research. Listed below are the study's hypotheses:

- (i) The adoption of CIRAD's aflatoxin-reducing program would enhance the welfare of Senegal's confectionery groundnut farmers.
- (ii) An overall welfare net-gain would be derived by Senegal from the adoption of the program.

The importance of groundnuts to Senegal's economy is a well-established fact. For many years, the groundnut crop has been the country's leading cash crop. Groundnut output has nevertheless, been characterized by considerable fluctuations. These may be attributed to factors such as the vagaries of the Sahelian weather, poor vegetation, and unstable producer prices. Senegal's groundnut production is characterized by a labor-intensive and rudimentary technology. Farmers produce three main types of groundnuts — oil groundnuts, confectionery groundnuts, and seed groundnuts. Problems facing the groundnut sector include inadequate rainfall, high input prices, pest infestation, and aflatoxin contamination. The problem of aflatoxin contamination is, however, to a large extent, confined to confectionery groundnuts; seed groundnuts are mainly used for replanting, while in the case of oil groundnuts, most of the toxins are eliminated during the oil extraction process.

The marketing of Senegal's groundnuts is carried out through the formal and informal sectors. The informal sector is, to a large extent, a gray market. The formal sector is made up of SONACOS, NOVASEN, SONAGRAINES³⁷, private sector agents, and farm cooperatives. The bulk of oil groundnuts are processed into oil, and seed groundnuts are usually marketed to farmers for replanting. Confectionery groundnuts on the other hand, are partly exported and partly processed into edible groundnut products and marketed locally. The direct purchase of confectionery groundnuts from farmers is dominated by NOVASEN through its Arachide de Bouche (ARB) program. The ARB program is a contract-farming scheme that employs many local agents to inspect the farming practices. Senegal's groundnut exports have declined over the years. The quantities of exports were at their peak for a greater part of the 1960s. Since the late 1960s however, there has been a general reduction in the quantities of groundnuts exported. Given its high dependence on Europe for the exports of groundnuts, Senegal's economy is likely to be adversely affected by the European Union's stringent aflatoxin-regulatory policy. The pricing of groundnuts on the world market is outside Senegal's control. This lack of control is basically due to the fact that the country's groundnut exports constitute a small percentage of the world market. The producer price received by Senegalese groundnut farmers was, for many years, under the control of the country's political authorities. Since 1996, however, the setting of the producer price has become the responsibility of an inter-professional committee.

The determination to minimize groundnut aflatoxin contamination in West Africa has spawned several research efforts. Institutions involved in these efforts include CIRAD, ICRISAT, ISRA, and USAID (through the Peanut CRSP). Potential technologies being explored include farming and post-harvest management practices, the use of biochemical mechanisms, and genetic control. The aflatoxin-reducing program being developed in Senegal's confectionery groundnut sector has several components. These components include seed and plant health, the identification and multiplication of new groundnut cultivars, mitigation of drought stress, the development of a GAP guide for confectionery groundnut production, and post-harvest management. Preliminary research results

³⁷ That is, prior to its demise in November 2001.

suggest that the program, if adopted, will increase significantly the output (and export) of high quality confectionery groundnuts (Sagarra 2002b).

This study employs the economic surplus technique to analyze the potential economic impact of aflatoxin-reducing research in Senegal's confectionery groundnut sector. The choice of this approach is informed by its appropriateness for assessing the impact of agricultural research. In spite of the various criticisms of this technique, it is still one of the most preferred methods for carrying out economic evaluations of research and technology. The economic surplus approach has been used in numerous studies. Those that have received attention in the present study include impact assessments of research relating to the following: a groundnut variety in Senegal (Soufi 2001), maize production in Kenya (Mills 1998), the Australian wool industry (Mullen and Alston 1990) and Peruvian agriculture (Norton, Ganoza, and Pomareda 1987).

In the recent past, the application of standards by countries has been characterized by controversy in international trade circles. This controversy stems from the realization that there is considerable latitude for the abuse of standard setting by employing it to restrict international trade and protect domestic industries. This abuse, together with the need to protect human, animal, and plant health, has led to the establishment of the SPS and TBT Agreements by the Uruguay Round of Multilateral trade negotiations. In an attempt to facilitate the economic analysis of technical trade barriers in a systematic way, Roberts, Josling, and Orden (1999) have proposed a classification scheme, as well as a modeling framework for assessing the trade effects of technical trade barriers. The empirical evaluation of the impact of SPS standards on food trade flows has been the focus of studies by Otsuki, Wilson, and Sewadeh [2001(a) and 2001(b)] and Wilson and Otsuki (2001). On the whole, these empirical studies suggest that developing countries would incur significant losses if aflatoxin standards that are more stringent (than the CODEX guidelines) are implemented. For example, in comparing the new EU aflatoxin standard to the CODEX regulation, Otsuki, Wilson, and Sewadeh (2001a) suggest that, even though the EU standard would reduce health risk by roughly 1.4 deaths per billion a year, it would lead to a US\$670 million (or 64 percent) reduction in African exports.

The present study uses an economic surplus model that incorporates trade, as well as, domestic production and consumption. Major assumptions made in the study include the following:

- i) the adoption of the aflatoxin-reducing program leads to a parallel downward shift in the export supply curve
- ii) the adoption of the aflatoxin-reducing program leads to a parallel upward shift in the domestic supply curve.

A key factor underlying these shifts is the price premium enjoyed by farmers from selling to the export market (through NOVASEN). While increasing economic surplus in the export sector, the program adoption reduces the domestic market's economic surplus. Thus, in terms of changes in economic surplus, the impact of the adoption of the aflatoxin-reducing program is the aggregate impact on the export and domestic markets.

Different assumptions about the effectiveness of the aflatoxin-reducing program lead to different program-induced net quantity gains. The index of program-effectiveness used in the analysis, is the program-induced percentage increase in high quality groundnuts. The scenarios of program-effectiveness examined are 30%, 40%, 50%, and 60% program-induced increases in high quality groundnuts. These scenarios of program-effectiveness are equivalent to "with-program" export shares of 78%, 84%, 90%, and 96%, respectively.

5.2 Results

The study's results are indicative of Senegal's potential benefits from research into the aflatoxin-reducing program. The results also suggest a positive relationship between program-effectiveness and farmers' net-gain, as well as, between program-effectiveness and the overall net-gain to Senegal's economy. In the least optimistic scenario, Senegal's economy derives an overall net-gain of US\$0.56 million, while the most optimistic scenario shows a net-gain of US\$4.25 million. In the aggregate, only consumers incur a loss as a result of the adoption of the aflatoxin-reducing program; with changes in the export sector leaving consumers unaffected, a decline in domestic sales of confectionery groundnuts leads to a fall in consumer surplus (i.e., ignoring the monetary value of health gains). The key conclusion of the study — that, the potential exists for

gains to be derived from aflatoxin-reducing research in Senegal's confectionery groundnut sector — is supported by the results. In the distribution of the research-induced producer surplus, the results suggest NOVASEN will continue to have a greater share than farmers. The results also suggest, that farmers' share will improve marginally with an increase in program-effectiveness. Farmers are however, likely to receive a lower share of producer net-gains so long as NOVASEN's contract farming scheme thrives.

In a nutshell, the results of the analysis support the hypotheses of the study. The adoption of the aflatoxin-reducing program is expected to improve the welfare of Senegal's confectionery groundnut farmers. Ignoring the health impact, the results further suggest that, the adoption of the aflatoxin-reducing program will result in a welfare loss to consumers. In the aggregate however, the adoption of the program is likely to be beneficial to Senegal, even though the net benefit is very low³⁸.

5.3 Recommendations

Given the suggested positive relationship between program-effectiveness and farmers' net-gain, as well as, between program-effectiveness and aggregate net-gain, improvements in the effectiveness of CIRAD's aflatoxin-reducing program would enhance the potential gains to Senegal's economy.

Many of the aflatoxin- and SPS-related problems faced by developing countries can be overcome through regional co-operation. For example, regional co-operation can facilitate the pooling of resources — such as collaboration in research — to enhance members' capacity for meeting aflatoxin-regulatory requirements. Such co-operation can also increase the political clout of members to ensure that their SPS-related interests are better addressed by the WTO. In spite of the problems that often weaken the effectiveness of regional co-operation, there is enough justification for Senegal to pursue such a strategy through her membership of the Economic Community of West African States (ECOWAS).

Furthermore, the capacity of developing countries to meet aflatoxin and other SPS-related requirements would be enhanced, if developed countries provide increased

³⁸ Given that the analysis did not cover every aspect of CIRAD's overall aflatoxin project, the net-benefits could well be understated.

technical and logistic assistance. This will go a long way to increase the capabilities of developing countries to prevent and eliminate aflatoxin contamination in groundnuts and other agricultural products.

The economic evaluation of the health impact of CIRAD's aflatoxin-reducing research is of crucial importance for analyzing the overall impact of the program on Senegal's economy. There is however, a dearth of such studies. It is therefore imperative that further research be expended in this direction.

5.4 Conclusion

The thrust of this study has been to evaluate the potential economic impact of research into the development of an aflatoxin-reducing program in Senegal's confectionery groundnut sector. Using an economic surplus model that incorporates trade, as well as, domestic production and consumption, the results of the analysis support the hypotheses of the study. The adoption of the aflatoxin-reducing program is expected to enhance the welfare of Senegal's confectionery groundnut farmers. Ignoring potential health gains, the results further suggest that, the adoption of the program will result in a welfare loss to consumers. A key conclusion of the analysis is that, even though the adoption of the aflatoxin-program is likely to be beneficial to Senegal's economy, the net benefit is very small.

It is recommended that Senegal and other developing countries pursue regional co-operation as an avenue for dealing with aflatoxin-related problems. The economic evaluation of the health impact of CIRAD's aflatoxin research should also engage the attention of researchers.

REFERENCES

- Akobundu, E. "Farm-Household Analysis of Policies Affecting Groundnut Production in Senegal." M.S. Thesis, Virginia Tech, 1998.
- Alston, J.M., G.W. Norton, and P.G. Pardey. *Science Under Scarcity*. Ithaca NY: Cornell University Press, 1995.
- Alston, J.M., and M.K. Wohlgenant. "Measuring Research Benefits Using Linear Elasticity Equilibrium Displacement Models." In J.D. Mullen and J.M. Alston. *The Returns to the Australian Wool Industry from Investment in R&D (appendix 2)*. Rural and Resource Economics Report No. 10. Sydney: New South Wales Department of Agriculture & Fisheries, Division of Rural and Resource Economics, 1990.
- Badiane, C. "Senegal's Trade in Groundnuts: Economic, Social and Environmental Implications." 2001. <http://www.american.edu/TED/senegal-groundnut.htm>
Accessed in November 2002.
- Badiane, O. "External Trade Pessimism and the Role of Regional Markets in the Groundnut Trade by AGC Countries." *Journal of African Economies*. Vol. 2, No.1(May 1993):1-23.
- Badiane, O., and S. Kinteh. "Trade Pessimism and Regionalism in African Countries: the Case of Groundnut Exporters." *IFPRI Research Report 97*, Washington D.C., 1994.
- Bergtold, J.S. "Projected Economic Impacts of the New Partnership Agreement Between the EU and ACP States on the Senegalese Groundnut Sector." M.S. Thesis, Virginia Tech, 2001.
- Caswell, N. "Peasants, Peanuts and Politics: State Marketing in Senegal, 1966-80." *Marketing Boards in Tropical Africa*. Kwame Arhin, Paul Hesp and Laurens van der Laan, eds., pp. 79-119. London: KPI Limited, 1985.
- CIRAD. "About CIRAD". 2001. <http://www.cirad.fr/presentation/en/cirad.shtml>.
Accessed in October 2002.
- Claassen, E. M., and P. Salin. "The Impact of Stabilization and Structural Adjustment Policies on the Rural Sector: Case Studies of Cote d'Ivoire, Senegal, Liberia,

- Zambia and Morocco.” U.N. Food and Agriculture Organization (FAO) Economic and Social Development Paper. No. 90. Rome, 1991.
- Coraf Action. “Groundnut Network. A Fruitful Partnership.” No. 8, April - June 1998. <http://www.coraf.org/action/ca8en.html>. Accessed in September 2002.
- DFID. “Impact of Sanitary and Phytosanitary Measures on Developing Countries”. <http://www.dfid.gov.uk/AboutDFID/files/itd/spsdc.pdf>. Accessed in August, 2002.
- Dimanche, P. “Les exportateurs d'arachide de bouche des pays du Sud pénalisés par les nouvelles normes sur l'aflatoxine édictées par l'Union européenne”, *Oléagineux, Corps Gras, Lipides*. Vol. 8, No. 3(May - June 2001): 237-38.
- Economist Intelligence Unit (EIU). Country Report: Senegal. <http://db.eiu.com/>. Accessed in 2002.
- EXTOXNET. “Pesticide Information Profiles.” 1996. <http://ace.ace.orst.edu/info/extoxnet/pips/chloroth.htm>. Accessed in September 2002.
- Food and Agriculture Organization (FAO). FAO Statistical Databases. <http://apps.fao.org/>. Accessed in 2002.
- Gaye, M. Personal Communication. African Institute for Economic Development and Planning, United Nations, Dakar, Senegal: July 18, 2000.
- ICRISAT. “Protecting the Environment”. http://www.icrisat.org/text/pubs/ir99/protecting_environment.htm. Accessed in September 2002.
- IFPRI. “Can Regional Trade Revitalize the African Groundnut Market?” *IFPRI Report*, Vol. 16, No. 1(February 1994): 2.
- IFPRI. *Senegal Groundnut Market Reform*, 1997, <http://www.ifpri.org/themes/mp02/senegal/sn.htm#top>.
- International Monetary Fund (IMF). *2001 International Financial Statistics Yearbook*. Washington DC, 2001.
- ITDG. “Groundnut Processing.” http://www.itdg.org/html/technical_enquiries/docs/groundnut_processing.pdf Accessed in October 2002.

- Jensen, M.F. "Reviewing the SPS Agreement: A Developing Country Perspective." Working Paper, Center for Development Research, Copenhagen, February 2002.
- Jones, F.T., M.J. Wineland, J.T. Parsons, and W.M. Hagler. "Degradation of aflatoxin by poultry litter." *Poultry Science*, 75(1996): 52-58.
- Krissoff, B., L. Calvin, and D. Gray. "Barriers to Trade in Global Apple Markets", *Fruit and Tree Nuts Situation and Outlook*, FTS-280. Washington DC: Econ. Res. Serv., U.S. Department of Agriculture. (August 1997): 42-51.
- Maftai, M. "Exporting Groundnuts." *International Trade Forum*, April-June 1999, p. 4.
- Masters, W.A., B. Coulibaly, D. Sanogo, M. Sidibe, and A. Williams. *The Economic Impact of Agricultural Research: A Practical Guide*. West Lafayette, IN: Department of Agricultural Economics, Purdue University, July 1996.
- Mills, B. (Ed.) *Agricultural Research Priority Setting: Information Investments for Improved Use of Research Resources*. The Hague: International Service for National Agricultural Research, 1998.
- Mills, B.F. "Ex Ante Research Evaluation and Regional Trade Flows: Maize in Kenya." *Journal of Agricultural Economics*. Vol. 49, No. 3(September 1998): 393-408.
- Mills, B., and M. Kamau. "Methods for Prioritizing Research Options." *Agricultural Research Priority Setting: Information Investments for Improved Use of Research Resources*. Bradford Mills, ed., pp. 53-77. The Hague: International Service for National Agricultural Research, December 1998.
- Mullen J.D., and J.M. Alston. "The Returns to the Australian Wool Industry from Investment in R&D." *Division of Rural and Resource Economics Report No. 10*. Sydney: New South Wales Department of Agriculture & Fisheries, 1990.
- Norton, G.W., V.G. Ganoza, and C. Pomareda. "Potential Benefits of Agricultural Research and Extension in Peru." *American Journal of Agricultural Economics*, Vol. 69, No.2 (May 1987): 247-57.
- Orden, D., and E. Romano. "The Avocado Dispute and Other Technical Barriers to Agricultural Trade under NAFTA." Paper presented to the conference "NAFTA and Agriculture: Is the Experiment Working?" San Antonio TX, November 1996.
- OT Africa Line. "Groundnuts News." <http://www.otal.com/cgum.htm>. Accessed in February 2002.

- Otsuki, T., J.S. Wilson, and M. Sewadeh. "Saving two in a billion: quantifying the trade effect of European food safety standards on African exports." *Food Policy* 26(2001): 495-514.
- . "What price precaution? European harmonization of aflatoxin regulations and African groundnut exports." *European Review of Agricultural Economics*. Vol. 28, No. 3(2001): 263-83.
- Paarlberg, P. L., and J. G. Lee. "Import Restrictions in the Presence of a Health Risk: An Illustration Using FMD." *American Journal of Agricultural Economics*. Vol. 80, No. 1(February 1998): 175-83.
- Peanut CRSP. *The Peanut CRSP Region Report for West Africa*.
<http://www.griffin.peachnet.edu/pnutcrsp.html>. Accessed in 2002.
- Queensland Government. "Better peanuts from better harvesting." *DPI News*, July 11, 2001. <http://www.dpi.qld.gov.au/news/NewsReleases/5797.html>. Accessed in 2002.
- Roberts, D., T.E. Josling, and D. Orden. *A Framework for Analyzing Technical Trade Barriers in Agricultural Markets*. Washington DC: U.S. Department of Agriculture, ERS Technical Bulletin No. 1876, March 1999.
- Sadoulet, E., and A. de Janvry. *Quantitative Development Policy Analysis*. Baltimore MD: The Johns Hopkins University Press, 1995.
- Sagarra, L. Personal communication, October - December, 2002.
- . "Rapport d'activités Campagne 2001." A CIRAD Report, March 2002.
- Sall, P.N. "Integrated Application of Sustainable Forest Management Practices Case Study: The Northwest Groundnut Basin Village Reforestation Project (PREVINOBA) and the Forestry Research Project in the Semi-Arid Zone of Senegal." July, 1996. http://www.nrcan.gc.ca/scf/kochi/papers/senegal_e.html. Accessed in 2002.
- Senegal. Direction De L'Agriculture, Division des statistiques agricoles. "Evolution Des Prix Agricoles Aux Pro." Personal Communication. July 2000.
- Sidibe, M. "A Farm Household Analysis of Technological Change and Structural Adjustment Policies in the Peanut Basin of Senegal." Ph.D. Dissertation, Purdue University, 2000.

- Soufi, W. "Agricultural research in Senegal: Economic surplus evaluation of the adoption of variety La Fleur 11 by peanut farmers." M.S. Thesis, Virginia Tech, 2001.
- Sullivan, J., V. Roningen, S. Leetmaa, and D. Gray. *A 1989 Global Database for the Static World Policy Simulation (SWOPSIM) Modeling framework*. Washington DC: US Department of Agriculture, Economic Research Service, Agriculture and Trade Analysis Division, May 1992.
- Sumner, D., and H. Lee. "Sanitary and Phytosanitary Trade Barriers and Empirical Trade Modeling." *Understanding Technical Barriers to Agricultural Trade*. Proceedings of a Conference of the International Agricultural Trade Research Consortium (IATRC). David Orden and Donna Roberts, eds., pp. 273-83. St. Paul MN: IATRC, January 1997.
- Thilmany, D. D., and C. B. Barrett. "Regulatory Barriers in an Integrating World Food Market." *Review of Agricultural Economics*. Vol. 19, No. 1(1997): 91-107.
- Trade Point Senegal. <http://www.tpsnet.org/Cahier/trade/AGRISEN/arabouche.htm>. Accessed in October 2002.
- US Department of State. *Background Note: Senegal*. January 2002. <http://www.state.gov/r/pa/ei/bgn/2862.htm>. Accessed in 2002.
- US Food and Drug Administration. *Food-borne Pathogenic Microorganisms and Natural Toxins Handbook*. <http://www.cfsan.fda.gov/~mow/chap41.html>. Accessed in 2002.
- Warning, M., and N. Key. "The Social Performance and Distributional Consequences of Contract Farming: An Equilibrium Analysis of the *Arachide de Bouche* Program in Senegal." *World Development*. Vol. 30, No. 2(February 2002): 255-63.
- Wilson, J.S., and T. Otsuki. *Global Trade and Food Safety: Winners and Losers in a Fragmented System*. Washington DC: Development Research Group (DECRG), The World Bank, 2001.
- WISARD Project Information. <http://www.wisard.org/wisard/shared/asp/projectssummary.asp?Kennummer=5481>. Accessed in September 2002.
- World Trade Organization (WTO). Committee on Sanitary and Phytosanitary Measures,

Submission by the Gambia. G/SPS/GEN/50. Geneva, 1998.

Zarrilli, S. "WTO Sanitary and Phytosanitary Agreement: Issues for Developing Countries." Working paper, South Center, Geneva, July 1999.

Vita

Louis Boakye-Yiadom received his B.A. (Economics with Statistics) and M.Phil. (Economics) degrees from the University of Ghana in 1989 and 1993, respectively.

Between 1995 and 2000, he was an active member of faculty in the Department of Economics, University of Ghana. Courses taught during this period include Principles of Economics, Economic Growth and Development, and Microeconomic Theory.

Having lived mostly in Ghana (a developing country), Louis Boakye-Yiadom has developed keen research interest in development economics, especially, the economics of poverty reduction. Of immense interest to him, is the formulation of appropriate economic and development policies to raise living standards. The training of economists is also high on his career agenda. He plans to pursue a Ph.D. (Economics) program soon.