IMPACT OF INTEGRATED CASSAVA PROJECTS IN THE NORTH COAST OF COLOMBIA

by

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July 11, 1992

Third Draft

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1. INTRODUCTION

Cassava (Manihot esculenta Crantz) is one of the most important sources of carbohydrates for rural and urban people throughout the developing world. World production in 1990 was estimated at 150 million MT (FAO, 1991). Also in Colombia, cassava plays an important role in the production system of the resource-poor small farmer, for its excellent adaptation to marginal soil conditions and unfavorable climates. The majority of cassava is grown for on-farm consumption and as an important cash-crop sold to urban markets. One of the most important cassava production zones of Colombia is the North coast region, which covers an area of around 120,000 Km^2 that is characterized by large plains, rolling hills, and an incidental mountainous zone. This region is also characterized by intermediately fertile soils, high temperatures (mean above 25° C), a long dry season (3-4 months) and a low to moderated rainfall (700-1500 mm/year). According to Janssen (1986), cassava accounted for 40% of the total small farmer income from agricultural production in the North coast of Colombia.

Traditionally, cassava in the North coast of Colombia has been marketed for fresh-human consumption and for the production of typical processed cassava products, also for human consumption. Cassava processing for industrial uses has only existed in the form of a small cassava starch plant near Barranquilla.

The Centro International de Agricultura Tropical (CIAT), based in Cali, Colombia, has conducted extensive research on cassava, for which it has a world mandate responsibility. During the 1970s cassava research was primarily targeted towards generating improved production technology components. At the end of that period, it became increasingly clear that small cassava farmers, facing considerable marketing risks were reluctant to experiment and adopt improved production technologies. Subsequently, at the beginning of the 1980s, it was hypothesized that the ability to increase cassava productivity depended on improving and stabilizing cassava markets. Lynam (1986) stated that "an alternative market for cassava, in most cases closely linked to more stable grain prices, will provide a price floor under cassava and because of the reduced risk, farmers will increase their cassava production. In the longer term as processing capacity becomes more generalized, a response due to more secure market access would also be expected". He also stated that cassava utilization technology associated with market development could have a direct impact on incomes in the region, but it was the secondary impact on production response that would deepen the income generation potential of the technology. As such, at CIAT a research approach was developed that incorporated cassava production, processing and marketing research in an integrated manner, called Cassava Integrated Projects[1].

A detailed ex-ante impact assessment study on the development of new cassava markets was conducted by Janssen (1986) and extended by Janssen and Lynam (1990), with the purpose of defining the pay-offs of alternative research strategies. This initial study of the cassava production system in the North coast of Colombia (Janssen, 1986), suggested that cassava's low productivity was related to the deterioration of fresh cassava demand and the instability of prices (besides exogenous factors like climatic variability). In order to increase the productivity, an incentive to adopt improved production technology was required. It was hypothesized that the existence of new markets would increase the demand for cassava and partially stabilize its prices. Facing less marketing risk, farmers would want to increase cassava productivity, by adopting improved technologies (and increase cassava area).

One of the technological options to diversify cassava markets was the development of the dry-cassava industry. This new industry would provide dried cassava chips as a raw material for the production of animal feeds which has been an industry under expansion since the 1980s. Although the price paid for cassava by the drying industry would be lower than the price paid by the fresh cassava market, the quality standards would be lower and a minimum price for cassava would be established since dry cassava prices would be tied to the minimum feed grain (sorghum) prices fixed by the government. In 1981, the Colombian government sponsored Integrated Rural Development (DRI) Program started a project for the development of a dry cassava industry in the North coast of Colombia with the collaboration of various national and international institutions. Subsequently, in 1982 the first cassava drying pilot plant, managed in the form of a small farmers

[1] For an extensive review of this approach, see Perez-Crespo (1991).

cooperative, started to produce dried cassava chips. Currently, more than 160 cassava drying plants have been constructed throughout Colombia. In addition, in Ecuador and Brazil a rapid adoption of the same cassava research and development model has been experienced.

Research can only be conducted efficiently and effectively when there is sufficient feed back to the research institutions (and donors) on the benefits and the distribution of its research investments. As such, adoption and impact studies form the last link in the development process of technology.

In order to review the effectiveness of cassava research and development efforts in the North coast of Colombia, a preliminary intent to assess certain ex-post aspects impact from the adoption of the cassava drying industry in the region was conducted by Cock et. al (1990). Their major conclusion was that the introduction of the cassava drying industry, besides improving the incomes of cassava producers, increased fresh cassava supplies, directly benefitting poor urban consumers through lower fresh cassava retail prices. However, the methodology scope and detail used in their study can be significantly improved upon.

This study is part of an extensive analysis on the adoption and impact of cassava technologies regarding Integrated Cassava Projects, that is being conducted by the Cassava Economics Section at CIAT. The current study however, concentrates only on the macro-economic impact of these projects. The general and main objective of this study is to determine the impact of the Integrated Cassava Projects in the North coast of Colombia and to quantify the benefits accruing to different groups of society.

The specific objectives of the study are to:

1) Quantify the relationships between input and output prices and volumes in cassava production, marketing, processing, and consumption. The analyses of these relationships are important to better understand the cassava system in the region and are essential to quantify the benefits to producers, market agents, processors, and

consumers. This knowledge is also necessary for future studies simulating the impact of new technologies or government policies.

2) Study and compare the fluctuation in cassava producer and consumer prices and the transmission between these prices, before and after the adoption of processing and production technologies.

3) Analyze the cassava supply response to the risk on prices due to its fluctuations.

4) Estimate actual per capita fresh cassava consumption in the region in order to compare current fresh consumption with the consumption before the adoption of technology. This estimation is necessary to test the hypothesis that technology-led increased supplies have lowered fresh cassava prices and augmented consumption.

5) Calculate the total benefits accrued to consumers, producers, market agents, and processors, and to determine how much of these benefits are due to the adoption of dry-cassava processing technology and improved production technology and how much of the benefits are due to other exogenous factors such as land reform or improvement on credit availability to the small cassava producers.

6) Based on the above results, analyze the implications of the cassava research and development approach, regarding the methodology and priorities for future cassava technology development.

At the same time, the following hypotheses stated by Lynam (1986) need to be tested, in order to provide feed-back to the Integrated Cassava Project research approach:

a) The development of an alternative market based on processed cassava increases the size of the total market for cassava, in most cases has more growth potential, and can result in a stable price floor under traditional markets.

b) A more expansive market with a stable floor price would provide incentives for the adoption of improved production technology.

c) Small-scale processing technology is most compatible with small-farmer production systems.

d) Wherever possible small-scale cassava producers themselves should do the processing in order to maximize the benefits of new market development.

e) Consumers will loose because of the increased competition for cassava.

f) Benefits to producers are expected to be distributed proportionally to relative farm size.

g) Farmers with more access to resources, such as land and credit, would be able to expand production more and therefore would benefit more.

h) Most of the benefits would come from lagged production technology adoption and less from the cassava drying technology itself.

The methodology of the study consists of the construction of a descriptive model of the North coast cassava system, which incorporates cassava production, marketing, processing, and consumption. This model is then displaced and converted to its log-linear form, so that the endogenous variables of the model, which are percentage changes of equilibrium prices and quantities, are expressed as a function of demand, supply, and substitution elasticities. In order to estimate the impact of technologies on equilibrium quantities and prices, the model simulates exogenous supply and demand shifts resulting from the two different technologies. The estimated changes on equilibrium prices and quantities resulting from each technology are then used to estimate the benefits received by the different groups in society from the adoption of that specific technology.

In order to optimize the neutrality of this impact assessment, CIAT sought the collaboration of an outside consultant, and a local university, in addition to its in-house economist in executing the study.

The paper is divided as follows. First, cassava production, processin marketing, and consumption are treated in separately sections. Thes sections are followed by an ex-post welfare analysis from the adoption c cassava drying and production technology which incorporates cassav production, processing, marketing, and consumption in a simultaneou equilibrium model. The last section includes a validation of the welfar analysis results, the main conclusions drawn from the study, and th implications for future research planning.

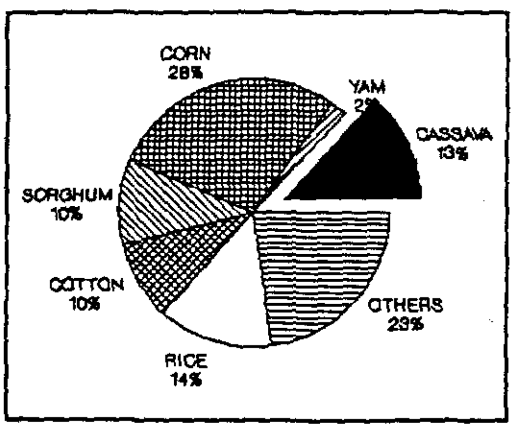
2. CASSAVA PRODUCTION AND SUPPLY IN THE NORTH COAST OF COLOMBIA

2.1 INTRODUCTION

The North coast of Colombia is the most important cassava production region of Colombia. This region produced 52% of total cassava production in the country during 1990.

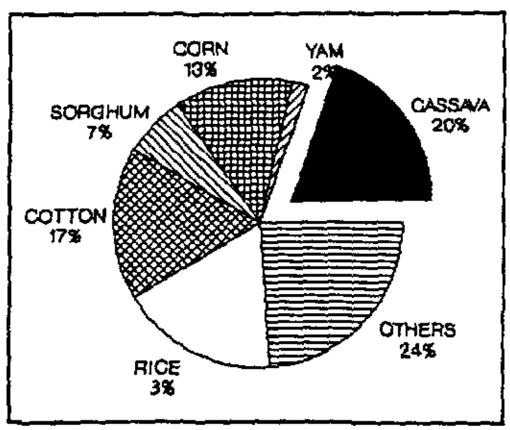
According to Janssen (1986), cassava, maize, and yam are produced in the North coast mainly by semi-subsistence farms which are devoted to labor-intensive food crops. In 1990, these three crops made up for 43% of total land under crops and 35% of the value of crop production (Figures 2.1 and 2.2) in the North coast of Colombia. On the other hand, cotton, sorghum, and rice are solely market-oriented cash crops which represented 34% of total land under crop production and 42% of its value of production during 1990. Cassava by itself accounted for 13% of the land under crops and 20% of the total value of crop production in the North coast of Colombia during 1990 (Figures 2.1 and 2.2).

Figure 2.1.--Share of Area Under Crops in the North coast of Colombia, 1990.



Source: Ministerio de Agricultura, Bogotá.

Figure 2.2.--Share of Value of of Crop Production in the North coast of Colombia, 1990.



Source: Ministerio de Agricultura, Bogotá.

Cassava production in the North coast increased at an average annual rate of 4.2% during 1975-81. The department with the highest increase was Atlántico (41.2%) followed by Bolívar (14.2%), Magdalena (12.1%), and Córdoba (1.5%). However, cassava production during this period decreased in Sucre by 4.4% annually (Table 2.1). This increase in cassava production, to a certain extent, could be related to the establishment in 1977 of the DRI-program as a reaction to the decreasing income basis of the small farmer. The emphasis of this program has been on production increases through the increase of credit. According to Janssen (1986), the increased credit availability had a marked effect on intensification of production by farmers included in the program during this period.

Table 2.1.--North Coast of Colombia Average Annual Growth in Production of Cassava.

Department	Average Annual Rate of Growth		
	76-81	82-86	86-91
Atlántico	54.09	-10.33	1.56
Bolívar	14.19	0.54	11.84
Córdoba	1.45	-1.41	42.90
Magdalena	12.07	-9.94	32.46
Sucre	-4.39	-11.50	26.52
Total North coast	4.18	-9.16	14.82

Source: "Ministerio de Agricultura - Subdirección de Producción Agrícola - SIAE." July, 1991.

This period of growth in cassava production was followed by a period of contraction. During 1981-86, production decreased at an annual rate of 9.16% in the region. The highest decrease was in Sucre, where cassava production decreased by 11.5% per year, followed by Atlántico (-10.3%), Magdalena (-9.9%), and Córdoba (-1.4%). In Bolívar production increased but only at an annual rate of 0.5%. (Table 2.1). One of the major causes of this decrease in production according to Janssen (1986), was that the production of cassava in the North coast in 1981 was extremely high

(774,000 MT), leading to strong price decreases. Many farmers could not find buyers for their crop and plowed the land without harvesting and were since then afraid to grow more cassava. Another cause for this decrease in cassava production was an intense drought in 1983, especially during the first three months of the cropping season which reduced the area harvested and the yields and at the same time the availability of seed for the 1984 cropping season. During 1985-91, cassava production in the North coast of Colombia increased at a high annual rate of 14.8%. The department with the highest increase was Córdoba, where production increase at an average annual rate of 42.9%, followed by Magdalena (32.5%), Sucre (26.5%), Bolívar (11.8%), and Atlántico (1.6%) (Table 2.1). This increase in production is due to an increase in the area of production (Table 2.2) and an increase in yields (Table 2.3).

The causes that lead to this high increase in cassava production in the region during 1986-1991, can be summarized as follows:

2.1.1 <u>Decreased Marketing Risk</u>

According to farm surveys conducted by Janssen in 1982, 42% of the farmers interviewed stated that the reason they did not grew more cassava was because of marketing problems. He also found that there was a considerable price variability through the years and within-years, therefore the risk involved in cassava production was very high. It was suggested that the establishment of cassava drying plants would establish a floor price for cassava, preventing cassava prices from having high fluctuations. This cassava floor price would rise the average expected price and the decrease in price fluctuations would decrease the variance in prices reducing the risk faced by the producers. As it can be noted from Figure 2.3, the prices paid to the producer by the drying plants did not vary much from year to year and an average floor price of 12,859 $.Col/MT (Constant 1988 $.Col). The standard deviation in producer prices for the fresh market, as a measure of year-to-year fluctuations in prices, until 1984 (when the dry plants began to be replicated) was 3,050; meaning that producer prices could be 3,050 $.Col (Constant 1988 $.Col) higher or lower from one year to another (an 18% fluctuation in cassava producer prices). After 1984, this fluctuation in prices decreased to only 1,650 $.Col (Constant 1988 $.Col), a 10% fluctuation in

Table 2.2.--North Coast of Colombia Average Annual Growth on Area in Cassava.

Department	Average annual rates of growth		
	75-80	80-85	85-91
Atlántico	41.20	-2.53	4.04
Bolívar	3.44	11.36	8.84
Córdoba	-4.53	7.06	24.69
Magdalena	10.89	-4.31	27.04
Sucre	-3.55	-7.17	26.52
Total North coast	1.69	-9.16	14.65

Source: "Ministerio de Agricultura - Subdirección de Producción Agrícola - SIAE." July 1991.

Table 2.3.--Cassava Yields in the North Coast of Colombia, 1982 and 1991.

Department	1982[a]	1991[b]	% Change in Yield
Atlántico	8.1	5.8	-28.40
Bolívar	7.5	11.4	52.00
Córdoba	6.8	12.0	76.47
Magdalena	6.9[c]	9.2	33.33
Sucre	7.0	10.7	52.86

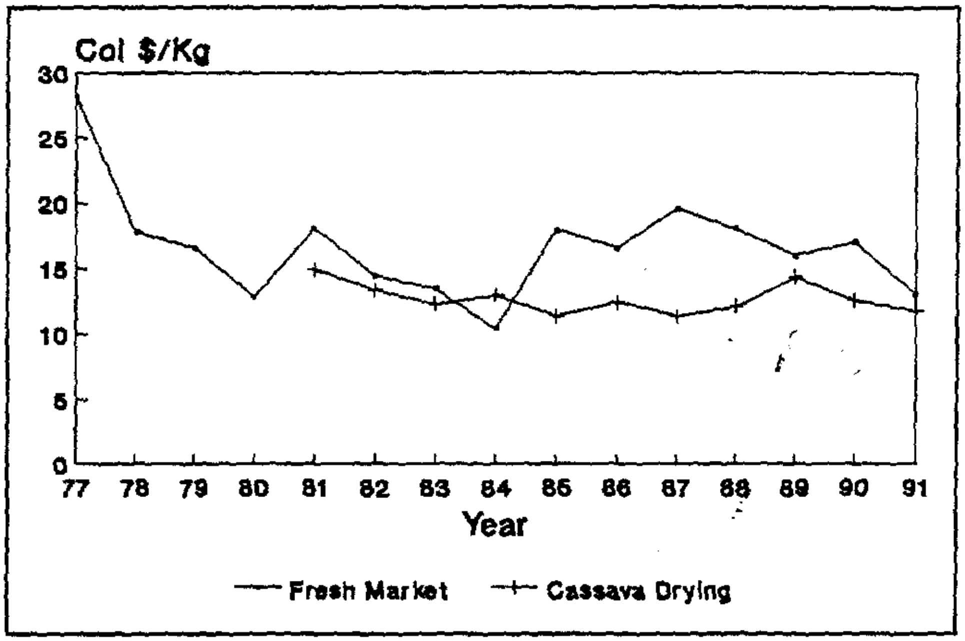
Source: [a] Janssen, W., 1982, "Producción, mercadeo, y el potencial de la yuca en los departamentos de Atlántico, Córdoba, Sucre, y Bolívar", CIAT mimeograph.

[b] Preliminary data, Cassava Adoption Survey, CIAT Cassava Economics, 1991.

[c] Estimation made by the authors.

prices, for the cassava sold to the fresh market and 530 Col $ (Constant 1988 Col $), only a 4% fluctuation in prices, for cassava sold to the drying plants. Janssen (1986), estimated that a partial stabilization in prices and an increase in expected prices would increase the supply of cassava as much as 70%.

Figure 2.3.--Cassava Producer Prices in the North coast of Colombia in 1988 Constant Prices, 1977-91.



Source: Central de Cooperativas de Reforma Agraria (CECORA) and DRI-CIAT Cooperative Project on Agro-Industrial Development of Cassava in the Atlantic coast of Colombia Annual Reports.

2.1.2 Adoption of Production Technology

According to the underlying philosophy of the Integrated Cassava Project, which was first developed in Colombia, the declining traditional markets for cassava during the early 1980s, did not offer incentives for cassava farmers to adopt technologies to increase production. The introduction of the dried cassava technology in the North coast, which broadened the demand for cassava and partially stabilized its prices, created incentives for the adoption of production technology at the farm level. In the short-run, farmers have the option to increase the area planted with cassava, decrease the fallow period and area, and decrease nonharvested cassava area. In the intermediate term, farmers will start to adopt new production technologies increasing cassava productivity.

Preliminary data of the Cassava Technology Adoption Survey, conducted by CIAT Cassava Economics Section (CIAT, 1992), show that cassava farmers in the North coast of Colombia have been adopting some components of improved cassava production technology. A comparison of the adoption of technological components between areas without drying plants and with low or nonexisting institutional presence (Level 3) and areas with cassava drying plants and with good institutional presence (Level 1) is presented in Table 2.4, showing that in the high influence area, adoption has been almost 20% higher than in the low influence areas.

2.1.3 Increase in Credit Availability for Small Farmers

Janssen (1986), also showed that 11% of the farmers did not have sufficient credit to extend their cultivation of cassava. Since most of the small farmers have also labor constraints during the planting and weeding season (april and may), an increase in the available credit could increase their herbicide use for weeding and/or use of machinery for land preparation. This use of machinery and/or herbicides will reduce labor needs during the peak months leading to an increase in their area planted with cassava. According with data obtained from the Colombian Ministry of Agriculture, in 1980, only 11,572 ha. of cassava (17.5% of the total area planted with cassava) were planted with credit facilities from governmental financial institutions. After 1980, the area of cassava planted with credit facilities increased in the north coast region. The area of cassava planted with credit from governmental financial institutions, increased in 1985, to 29,666 ha. of cassava (48.9% of the total area planted with cassava) and in 1987, to 40,716 ha. of cassava (54.9% of the total area planted with cassava).

Table 2.4.--Adoption of Cassava Production Technologies in the North Coast of Colombia, by Level of Technology Influence, 1991.

	Technology Influence Level	
	1[a]	3[b]
	% Respondents	
Adopted at least on production technology component	78	59
Received technical assistance	55	10
Vertical planting position	65 (42)[c]	58 (54)
Herbicide use	64 (35)	34 (20)
Machinery use in land preparation	73 (37)	22 (13)
Increased planting density	62 (18)	47 (44)
Stake treatment	18 (3)	3 (2)

Source: Preliminary data, Cassava Technology Adoption Survey, CIAT Cassava Economics, 1991.

[a] Level 1: Region with cassava drying plants, established before 1988 and with good institutional presence.

[b] Level 3: Region without cassava drying plants and with low or nonexisting institutional presence.

[c] The numbers on parentheses are the percentage of respondents that used the technology component before.

2.1.4 Land Reform

In 1982, Janssen also found that 38% of the farmers did not increase its cassava production because they lacked land. During the late 1980's, the Colombian Agrarian Reform Institute (INCORA) defined the land situation of many small farmers, which in turn increased their area planted in cassava, increasing its production. Table 2.5, shows the number of hectares adjudicated to small farmers in the North coast region by the "Colombian Land Reform Program". This data shows that Sucre was the department where the highest number of hectares was adjudicated by the land reform program, followed by Córdoba, Bolívar, César, Magdalena, and Atlántico. In the last two decades, 295,454 ha of land was adjudicated by the land reform program in the region. Of the land adjudicated in the last twenty years, 184,134 (62.3%) was adjudicated between 1986-91.

Table 2.5.--Land Adjudicated to Small Farmers by INCORA in the North coast of Colombia.

Department	Total Number of Adjudicated Hectares of Land			
	1969-79	1980-85	1986-91	Total
Atlántico	3,226	4,493	9,310	17,029.00
Bolívar	6,644	14,557	34,282	55,483.00
César	11,394	14,676	17,926	43,996.00
Córdoba	6,881	13,132	43,218	63,231.00
Magdalena	2,895	4,403	22,827	30,125.00
Sucre	12,844	16,174	56,571	85,589.00
Total North coast	43,884.00	67,435.00	184,134.00	295,453.00

Source: INCORA, Informe Comparativo de Ingreso y Salida de Tierras, 1961-1992.

2.1.5 Substitution of Yam Production Area With Cassava

Since 1985 there has been an increasing incidence of Antracnosis disease in yam production in the North coast of Colombia. In 1990, this disease decreased yam production and area significantly. Yam Production in the North coast of Colombia, which was increasing at an annual rate on 10.6% per year between 1980-1986, after 1986 decreased at an annual rate of -0.21%. The most affected department was Sucre, were production and area on yam decreased at an average annual rate of 55 and 44%, respectively, since 1986. (Table 2.6). Part of the area that was cultivated with yam was substituted for cassava, increasing total area and production of cassava.

Table 2.6.--Average Annual Change on Yam Area and Production in the North Coast of Colombia:

Year	Average Annual Rate of Change (%)							
	Bolívar		Córdoba		Sucre		North coast	
	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.
80-86	13.50	22.81	13.67	13.67	-1.68	3.15	10.56	6.63
86-91	26.62	5.34	2.34	2.34	-43.99	-54.99	-10.86	-0.21

Source: "Anuario Estadístico del Sector Agropecuario", Colombian Ministry of Agriculture, July, 1991.

Because of this high increase in cassava production in the late 1980s and the partial stabilization of prices, cassava producers have been benefitted in several ways besides income increase and employment generation. In order to calculate the benefits received by the cassava producers and determine by which extent these benefits are due to the partial stabilization of prices by the cassava drying plants and the adoption of cassava production technology, it is important to better understand the factors that affect the production and supply of cassava in the North coast of Colombia and to calculate the magnitude of these effects.

In the next section of the study a simple econometric model is developed in order to calculate the effect of changes in prices and risk in the supply of cassava in the North coast of Colombia. Also a cassava production cost function will be estimated in order to calculate the effect of changes on input prices on their demand and to estimate an alternative measure of the elasticity of supply of cassava.

2.2 METHODOLOGY

2.2.1 Partial Adjustment Nerlovian Model

The cassava production in the North coast will be estimated making use of a "Partial Adjustment Nerlovian Model" like the one utilized by Ramírez and Castillo (1986). The model assumes that because of constraints like lack of credit, land, risk aversion, and uncertainty; producers only change their total level of production in a given year in a proportion (γ) from the level of production that will give the highest economic return. The model used by Ramírez and Castillo (1986), will be modified for purposes of this study in two ways: 1) a variable to account for the risk involved in the fluctuation of cassava prices will be added to the model, in the form of the standard deviation of prices, and 2) the price received by producers for competitive products will be omitted because of lack of data and simplicity. As such, the model to estimate the supply of cassava is the following:

(2.1) $$QC = \gamma\beta 0 + \gamma\beta 1 * PC_{t-1} + (1-\gamma) * QC_{t-1} + \gamma\beta 3 * SD_{t-1} + \gamma\beta 4 * T + \gamma\mu_t$$

where:

QC = quantity of cassava produced in the farm,
PC_{t-1} = average price received by the producer in the previous year,
QC_{t-1} = total cassava production in the previous year,
γ = partial adjustment coefficient,
SD_{t-1} = price standard deviation in the previous year,
T = trend variable, and
μ_t = stochastic error.

From equation (2.1), the price supply elasticities are estimated in the following manner:

(2.2) $\epsilon c^s = \beta 1 * (PC/QC)$ where: ϵc^s = short-run price elasticity of supply.

(2.3) $\epsilon c^l = (\beta 1/\gamma) * (PC/QC)$ where: ϵc^l = long-run price elasticity of supply.

where: $(1-\gamma) = \beta 2$, therefore $\gamma = 1-\beta 2$. The risk response elasticity (σc) is estimated by using the following formula:

(2.4) $\sigma c = \beta 3 * (SD/QC)$.

2.2.2 <u>Cassava Production Cost Function Model</u>

A translog cost function was used for the estimation of the effect of changes on input prices on input demand and the substitution between the different inputs in cassava production, and the effect of output price changes on the quantity of cassava produced in the north coast of Colombia. The translog cost function was proposed as an approximation to unknown cost or production functions. It is appropriate because it does not impose stringent conditions on the parameters. A detailed discussion of the advantages of using the cost function approach over the estimation of a profit and/or a production function can be found in Binswanger (1974). The translog cost function has been used in many studies. Binswanger (1974), used the function to derive estimates of elasticities of derived demand and substitution of the U.S agricultural sector. Kako (1978), estimated a translog cost function to analyze the derived demand for inputs in the production of rice in Japan. Lopez (1980), estimated the demand for inputs in agricultural production in Canada by using the cost function approach. Ray (1982) specified a translog cost function to analyze the U.S. agricultural production in a multi-output context. Antle and Aitah (1983), used the function to investigate the structure of Egyptian rice technology and used these findings to answer some policy questions.

The following cassava production function was assumed,

(2.5) $Qc = f(Qma, Ql, Qo)$

where:
- Qc = quantity of cassava produced on the farm,
- Qma = number of hours of machinery used in land preparation,
- Ql = number of day worked on cassava production, and
- Qo = quantity of other inputs used in cassava production, such as the quantity of herbicide use.

Therefore, it is assumed that adopters of cassava production technology in the North coast show the following cost function,

(2.6) $Cc = Cc(Qc, Pma, Pl, Po)$

where:
- Cc = cost of cassava production per hectare,
- Pma = cost of preparing one hectare of land with machinery,
- Pl = the daily wage on cassava production times the number of day works of labor needed per hectare,
- Po = a price index of other inputs, such as herbicide and seed, used on the production of cassava.

According to Ray (1982), the cost function of cassava production by technology adopters, in its trans-logarithmic form, is the following:

(2.7) $$\ln Cc = a0 + ac*\ln Qc + acc*(\ln Qc)^2 + bma*\ln Pma + bl*\ln Pl + bo*\ln Po + 1/2*bmama*(\ln Pma)^2 + 1/2*bmal*(\ln Pma*\ln Pl) + 1/2*bmao*(\ln Pma*\ln Po) + 1/2*bll*(\ln Pl)^2 + 1/2*blma*(\ln Pl*\ln Pma) + 1/2*blo*(\ln Pl*\ln Po) + 1/2*boo*(\ln Po)^2 + 1/2*boma*(\ln Po*\ln Pma) + 1/2*bol*(\ln Po*\ln Pl) + bmac*(\ln Pma*\ln Qc) + blc*(\ln Pl*\ln Qc) + boc*(\ln Po*\ln Qc)$$

Since the translog cost function can be regarded as a quadratic approximation to the unspecified "true" cost function,

(2.8) $bmal = blma;\ bmao = boma;\ blo = bol$

Ray (1982) points out that one problem with multi-input cost functions is that, even for a few inputs, the number of parameters to be estimated is large. Moreover, with time-series observations needed for so many variables, it is likely to encounter severe multicollinearity problems and the estimation of the cost-function as a single-equation model may be either impossible or inappropriate. Therefore, estimating the full dual system (the cost and share equations together) should be more efficient and compensates for the information inadequacy in equation (2.7) alone.

Assuming that producers choose a cost minimizing combination of factors, and differentiating equation (2.7) using Shephard's lemma leads to the following cost share equations:

(2.9) $$Sma = bma + bma*lnPma + bmal*lnPl + bmao*lnPo + bmac*lnQc$$

(2.10) $$Sl = bl + bl*lnPl + bmal*lnPma + blo*lnPo + blc*lnQc$$

(2.11) $$So = bo + bo*lnPo + bmao*lnPma + blo*lnPl + boc*lnQc$$

where: $Sma = (Pma*Qma)/Cc$

$Sl = (Pl*Ql)/Cc$

$So = (Po*Qo)/Cc$

The following restrictions have to be included in the model in order to assume linear homogeneity in input prices,

(2.12) $$bmama + bmal + bmao = 0$$

(2.13) $$bll + bmal + blo = 0$$

(2.14) $$boo + bmao + blo = 0$$

(2.15) $$bmac + blc + boc = 0$$

Let define, *Qi* as the quantity of input *i*, *Pi* the price of input *i*, *Si* the production cost share of input *i* (i = ma, l, o).

Based on the input demand functions derived by Shephard's lemma (equations 2.9, 2.10 and 2.11), and using the above definition of Si the following relation is obtained:

(2.16) $$Si = Qi*Pi/Cc = \delta lnCc/\delta lnPi$$

Solving for Qi, gives:

$$(2.17) \qquad Qi = (Cc/Pi)(\delta lnCc/\delta lnPi)$$

Converting the function to logarithms, yields:

$$(2.18) \qquad lnQi = lnCc - lnPi + ln(\delta lnCc/\delta lnPi)$$

Based on expression (2.18), the own-price and cross-price elasticities of demand for the inputs (η_{ii}, η_{ij}, respectively) can be estimated with the following derivations:

$$(2.19) \qquad \eta_{ii} = \delta lnQi/\delta lnPi = \delta lnCc/\delta lnPi - 1 + \delta ln/\delta lnPi(\delta lnCc/\delta lnPi)$$

$$\eta_{ii} = Si - 1 + bii/Si$$

$$(2.20) \qquad \eta_{ij} = \delta lnQi/\delta lnPj = \delta lnCc/\delta lnPj - \delta lnPi/\delta lnPj + \delta ln/\delta lnPj(\delta lnCc/\delta lnPi)$$

$$\eta_{ij} = Sj + bij/Si$$

Allen partial elasticities of substitution between inputs, (σ_{ij}), can be estimated from the estimated elasticities of demand for the factors of production with the following expression suggested by Binswanger (1974),

$$(2.21) \qquad \sigma_{ij} = \eta_{ij}/Sj$$

Also according to Kay (1982), if we assume marginal cost pricing for the outputs, the following relations are obtained,

$$(2.22) \qquad Yc = \delta lnCc/\delta lnQc = (\delta Cc/\delta Qc)*(Qc/Cc) = Pc*Qc/Cc$$

This leads to the following "revenue share" equation,

$$(2.23) \qquad Yc = ac + acc*lnQc + bmac*lnPma + blc*lnPl + boc*lnPo$$

Solving equation (2.22) for Pc,

(2.24) $$Pc = (Cc/Qc)*(\delta lnCc/\delta lnQc)$$

Converting to logarithms,

(2.25) $$lnPc = lnCc - lnQc + ln(\delta lnCc/\delta lnQc)$$

Based on expression (2.24), the price-flexibility of supply of cassava on the farm (ξ_c) can be estimated with the following derivation,

(2.26) $$\xi_c = \delta lnPc/\delta lnQc = \delta lnCc/\delta lnQc - \delta lnQc/\delta lnQc + \delta ln/\delta lnQc(\delta lnCc/\delta lnQc)$$

$$\xi_c = Yc - 1 + acc/Yc$$

Since the price-elasticity of supply of cassava on the farm (e_s) is by definition $1/\xi_s$, then,

(2.27) $$e_c = 1/(Yc - 1 + acc/Yc)$$

2.3 EMPIRICAL FINDINGS AND RESULTS

2.3.1 Results from the Partial Adjustment Nerlovian Model

The model is estimated using secondary data from 1978-1991. Data on annual cassava production was obtained from the Colombian Ministry of Agriculture. Prices paid to the producer for fresh market (PCF) were obtained from INCORA and CECORA. Cassava prices paid to the producer by the cassava drying plants (PCD) come from the Annual Reports of the Cooperative Project DRI-CIAT on Agro-Industrial Development of Cassava in the Atlantic coast of Colombia. The average weighted producer price (PC) is calculated by using the following formula:

(2.28) $$PC = scf_t*PCF_t + scd_t*PCD_t$$

where: scf_t = the share of the production that went to the fresh market in year t, and

scd_t = the share of the production that went to the cassava drying plants in year t.

The standard deviation of prices is calculated according to Janssen by aggregating the random within-year price standard deviation and the year-to-year price standard deviation. A proxy for the within-year standard deviation on producer prices is calculated from Sincelejo (a major cassava production area in the North coast of Colombia) monthly consumer prices reported by DANE (Departamento Administrativo Nacional de Estadística). The trend variable takes values of one for the first year, two for the second year, etc.

The model's parameter estimates with t-statistics are reported in Table 2.7. For all five departments and the whole North coast region the effect of prices on the supply of cassava is positive, but not highly significantly different from zero with the exception of Magdalena. Prices received by the farmer in the previous year have a statistically significant effect ($\alpha = 0.05$) on cassava supply for Magdalena and at $\alpha = 0.25$ for Sucre. For the whole North coast and Bolívar the effect of prices on cassava supply is only significant at a 0.50 confidence interval. This low response to prices may be explained by the constraints that the small farmers face to increase their production such as lack of credit and land, risk aversion, and uncertainty.

As can be seen in Table 2.8, the partial adjustment coefficient (γ) for Magdalena is equal to one, which means that cassava producers in Magdalena are less limited and hence, can change their level of production from year to year in order to get the highest economic return. Therefore, they can react in a shorter time to changes in prices and their short-run price-elasticity of supply of cassava is equal to their long-run price-elasticity of supply.

For the case of Bolívar, Córdoba, and Sucre, the partial adjustment coefficients are smaller than one (0.47, 0.39, and 0.17, respectively), which means that cassava producers in these three departments have constraints to react rapidly to changes in prices in order to get the highest economic returns.

Table 2.7.--Partial Adjustment Nerlovian Production Model Parameter Estimates.

	Parameter Estimates						
	Const.	Pc_{t-1}[a]	SD_{t-1}[b]	Qc_{t-1}[c]	T[d]	R^2[e]	DW[f]
North coast	-26613	9080	-11.67	0.79	15565	0.85	2.25
	(-0.11)[g]	(0.70)	(-2.74)	(4.20)	(2.36)		
Atlántico	111350	769	-1.88	-0.006	-2328	0.20	2.06
	(1.91)	(0.31)	(-1.16)	(-0.02)	(-0.93)		
Bolívar	57531	1224	-2.86	0.53	3978	0.79	1.94
	(1.28)	(0.62)	(-2.16)	(2.32)	(1.71)		
Córdoba	11802	691	-2.84	0.61	4674	0.69	1.91
	(0.25)	(0.29)	(-1.78)	(2.92)	(2.19)		
Magdalena	-131860	15563	-3.53	-0.04	512	0.61	2.24
	(-1.10)	(2.56)	(-1.71)	(-0.14)	(0.15)		
Sucre	-88219	5122	-2.80	0.83	5737	0.76	2.11
	(-0.97)	(1.25)	(-1.84)	(3.35)	(2.28)		

[a] PC_{t-1} = Average Price Received by the Producer in t-1 in 1988 Constant Prices ($/MT)

[b] SD_{t-1} = Cassava Price Standard Deviation ($/MT)

[c] QC_{t-1} = Total Cassava Production in t-1 (MT)

[d] T = Trend

[e] R^2 = Coefficient of Determination

[f] DW = Durbin-Watson Statistic

[g] t-Statistics are in Parentheses

On the other hand, cassava producers have a significant response to changes in price variability. In Table 2.7, the parameter estimates for the standard deviation on prices show that in the whole North coast region and in the five individually estimated departments, farmers react negatively to an increase in the variability of prices (α=0.05). These results are consistent with the findings of Janssen (1986), who states that the price risk causes producers to react less to changing prices and that their risk aversion leads to a considerable decrease in the area in cassava in favor to other crops or pasture.

In the whole North coast region and in the departments of Sucre, Bolívar, and Córdoba there has been a significant tendency to increase production ($\alpha=0.01$) for reasons other than price increases or the reduction in price variability. In the North coast of Colombia there has been a tendency to increase production by 15,565 MT per year, on average. The department with the highest tendency to increase cassava production was Sucre, where there has been a tendency to increase production at an average of 5,737 MT per year, followed by Córdoba (4,674 MT per year) and Bolívar (3,978 MT per year). Contrary to the results of these three departments, there has been no significant tendency to increase or decrease production in the departments of Atlántico and Magdalena. These results are consistent with the CIAT's Cassava Adoption Survey preliminary results, which show that the adoption of cassava production technology in Sucre, Bolívar, and Córdoba was higher than in Atlántico and Magadalena. To some extent, this tendency to increase production in Sucre, Bolívar, and Córdoba could also be a result of the land reform program that gave land to small landless producers, the improvement in credit availability to small farmers, and the substitution of land planted with yam for cassava.

Short and long-run price elasticities of supply of cassava, the coefficient of partial adjustment, and the elasticity of risk response estimated for the North coast of Colombia are reported in Table 2.8. The short-run price-elasticity of supply of cassava (ϵcs) is positive for the whole region and all the departments, but not highly significant with the exception of Magdalena were the short and long-run price elasticities are high and significantly different from zero ($\alpha=0.01$). For the whole region this elasticity is low (0.30), meaning that a 1% increase in prices will only increase cassava production by 0.3%. The department with the highest short-run price-elasticity of supply is Magdalena, with a value of 2.19, followed by Sucre (0.75), Atlántico (0.16), Bolívar (0.15), and Córdoba (0.11).

In the long-run, cassava producers in the whole region have a higher price-elasticity of supply (1.42), meaning that a 1% increase in cassava prices paid to the producer will increase their production by 1.42% in the long-run. The department with the highest long-run price-elasticity of supply is Sucre, where it is equal to 4.33, followed by Magdalena (2.19), Bolívar (0.31), Córdoba (0.30), and Atlántico (0.16). It should be noted that the department with the lowest response to changes in prices is Atlántico, which is the department that hosts the smallest farms in the region and therefore producers face a higher land constraint. In this department there is also a higher competition for labor because of the proximity of the most important urban area in the North coast (Barranquilla).

The price-supply elasticities estimated in this study are similar to the ones reported by Rojas (1986) for Colombia, which are 0.29 in the short-run and 1.68 in the long-run. Janssen (1986), in a cross-sectional study and without differentiating between the short and the long-run, reports price-elasticities of supply for cassava in the North coast of Colombia of 0.65 for small farms (< 3 ha), 2.05 for middle size farms (3 - 8 ha), and 3.27 for large farms (> 15 ha).

Table 2.8.--Cassava Production Elasticities for the North Coast of Colombia at the Sample Means, 1978-1991.

Region	εcs[a]	γ[b]	εcl[c]	σc[d]
North coast	0.30	0.21	1.42	-0.23
	(0.70)•	(1.13)	(0.87)	(-2.74)
Atlántico	0.16	1.00	0.16	-0.28
	(0.31)	(3.04)	(0.32)	(-1.16)
Bolívar	0.15	0.47	0.31	-0.25
	(0.62)	(2.08)	(0.66)	(-2.16)
Córdoba	0.11	0.39	0.30	-0.21
	(0.29)	(1.83)	(0.30)	(-1.78)
Magdalena	2.19	1.00	2.19	-0.30
	(2.56)	(3.34)	(3.05)	(-1.71)
Sucre	0.75	0.17	4.33	-0.25
	(1.25)	(0.70)	(0.75)	(-1.83)

[a] εcs = Short-Run Price-Supply Elasticity

[b] εcl = Long-Run Price-Supply Elasticity

[c] γ = Partial Adjustment Coefficient

[d] σc = Risk Response Elasticity

• t-Statistics are in Parentheses

The elasticities of response to risk (σy) are significantly different from zero ($\alpha = 0.01$) for the whole region and for all the departments with the exception of Atlántico. The risk response elasticity for the whole region is equal to -0.23, meaning that a decrease of 1% in the fluctuation of cassava prices will increase the production of cassava by 0.23%.

2.3.2 Results from the Estimation of the Cassava Production Cost Function

The translog cost function was estimated with annual time series data from INCORA (1974-91). The results should be taken with caution since the data on cassava production costs was calculated assuming the adoption of some technological components, such as machinery use for land preparation and herbicide use. Therefore, the results of this estimation are not representative of all the cassava producers in the North coast of Colombia, but of those farmers who adopted some technology components. The estimated parameters of the translog cost function system (equations 2.7, 2.9, 2.10, and 2.11), with restrictions (2.8) and (2.12)-(2.15), are reported on Table 2.9.

Table 2.9.--Estimated Coefficients of the Cassava Production Cost Function, 1974-1991.

Parameter	Value	t-Statistic
A0 (intercept)	7.38	1.68
AC	-0.45	-0.62
ACC	-0.04	0.70
BMA	-0.07	-0.34
BL	1.01	3.30
BO	-0.76	-3.58
BMAL	0.07	7.51
BMAO	-0.08	-8.44
BLO	-0.08	-8.19
BLC	-0.04	-1.38
BOC	0.02	1.01

Even though the parameters estimated by the translog cost function do not have a clear economic meaning, the cost of production is explained mainly by the price of labor and other inputs, and the interaction between the price of inputs. The parameters estimated with the cassava production cost function, were used to estimate the own-price elasticities of demand of machinery (η_{ma}), labor (η_l), and other inputs (η_o), according to equation (2.19). The cross-price elasticities of demand for machinery with respect to labor and other inputs (η_{mal} and η_{mao}, respectively), for labor with respect to machinery and other inputs (η_{lma} and η_{lo}, respectively), and for other inputs with respect to machinery and labor (η_{oma} and η_{ol}, respectively) were estimated by using equation (2.20). Allen elasticities of substitution between machinery and labor (σ_{mal}), machinery and other inputs (σ_{mao}), and labor and other inputs (σ_{lo}) were estimated according with equation (2.21). By assuming marginal cost pricing for the outputs, the elasticity of supply of cassava on the farm (ε_c) can be estimated by using equation (2.27).

Table 2.10 shows that the estimated own-price elasticities of demand for the inputs in the production of cassava are inelastic ($< |1|$). However, the own-price elasticity of demand for machinery is the highest in absolute terms, followed by the elasticity of demand for labor and other inputs. If the cost of machinery increases by 1%, its demand will decrease by 0.78%. If the same happens with the cost of labor and other inputs, their demand will decrease by 0.41 and 0.09 %, respectively.

The cross-price elasticities of demand between inputs are also inelastic ($< |1|$). Machinery and other inputs, such as herbicides, are substitutes for labor in the production of cassava in the North coast, but machinery and other inputs behave as complements in cassava production. The highest cross-price elasticity of demand is the one for machinery with respect to labor. A 1% increase on farm daily wages, will increase the demand for machinery by 0.96%; but on the other hand, an increase in the cost of machinery of 1% will only increase the demand for labor by 0.31%.

The cross-price elasticity of demand for other inputs with respect to labor is also important, but has a lower absolute value than the cross-price elasticity of demand for machinery with respect to labor. An increase in the farm daily wages of 1% will produce a 0.24% increase in the demand for other inputs, such as herbicides. However, a 1% increase in the price for other inputs will only increase the demand for labor by 0.09%.

Table 2.10. Own-price and Cross-price Elasticities of Demand for Inputs, Elasticities of Substitution between Pairs of Inputs, and Output-supply Elasticities for the Production of Cassava, at the Sample Means.

Elasticity Estimate	Value	t-Statistic
Own-price elasticity of demand for machinery (η_{ma})	-0.78	-21.37
Own-price elasticity of demand for labor (η_{l})	-0.41	-45.75
Own-price elasticity of demand for other inputs (η_{o})	-0.09	-1.23
Cross-price elasticity of demand for machinery with respect to labor (η_{mal})	0.96	19.33
Cross-price elasticity of demand for machinery with respect to other inputs (η_{mao})	-0.18	-3.76
Cross-price elasticity of demand for labor with respect to machinery (η_{lma})	0.31	19.32
Cross-price elasticity of demand for labor with respect to other inputs (η_{lo})	0.09	5.88
Cross-price elasticity of demand for other inputs with respect to machinery (η_{oma})	-0.15	-3.76
Cross-price elasticity of demand for other inputs with respect to labor (η_{ol})	0.24	5.88
Elasticity of substitution between machinery and labor (σ_{mal})	1.64	19.33
Elasticity of substitution between machinery and other inputs (σ_{mao})	-0.80	-3.76
Elasticity of substitution between labor and other inputs (σ_{lo})	0.42	5.88
Own-price elasticity of supply of cassava on the farm (e_{c})	1.01	31.70

The elasticity of substitution estimates, show that there are more substitution possibilities between labor and machinery use than between labor and other inputs. A 1% increase in daily wages with respect to the cost of machinery, will increase the use of machinery with respect to labor by 1.64%. On the other hand, an increase of 1% in daily wages with respect to the price of other inputs, will only increase the use of other inputs with respect to labor by 0.43%. The negative elasticity of substitution between machinery and other inputs is a consequence of the complementary of these two inputs.

The own-price elasticity of on-farm cassava supply estimated by using the cassava production cost function of technology adopters, shows that cassava producers who adopt some technological components respond to price changes. The estimated on-farm cassava supply elasticity of technology adopting producers is unitary, meaning that a 1% increase in the cassava producer price, increases the supply of cassava on the farm by the same 1%.

2.4 CONCLUSIONS OF CASSAVA PRODUCTION ANALYSES

Even though the estimation of the cassava production function shows that producers who adopt technology and do not have any production constraints adjust their production to changes on cassava producer prices, the supply of cassava does not seem to significantly respond to changes in producer prices. There were mainly two factors that limited the response of cassava supply to price changes. The first factor is the risk involved on the price variability of cassava, which limits the response of farmers to price changes because of his fear of potential low sale prices. Another factor that limited and to some extend still limits the response of cassava farmers to price changes is the availability of land and credit.

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During the late 1980s in the North coast of Colombia, cassava production increased significantly, due to the increase in area planted and yields. This increase in cassava supply is a result of the partial stabilization of cassava producer prices because of the successful introduction of the cassava drying technology, the adjudication of land to small farmers as a consequence of the land reform program, and an improvement in the credit availability for cassava production. There has also been a significant substitution of yam production for cassava because of the increasing incidence of Antracnosis disease in yam in the region. On the other hand, cassava producers, during the 1980s, had been adopting more cassava production technology components because of the improvement in the cassava market system which has made the production of the crop more attractive.

In terms of input demand in cassava production in the North coast of Colombia, there seems to be significant opportunities for substitution between labor and machinery, and labor with other inputs (especially herbicides). These results coincide with the fact that the most important cassava production technology components adopted by cassava farmers were the use of machinery for land preparation and herbicides for weeding. One of the causes for this substitution of labor for other inputs, could be the increased demand for labor in the region by the cassava drying plants and the increased cassava production. This increased demand for labor may have put an upward pressure on wages, especially during the peak seasons of planting, weeding, and harvesting, resulting in the substitution of machinery and herbicides for labor in cassava production.

On the other hand, other cassava production technologies adopted by cassava farmers in the North coast are mainly cultural practices, which do not require, as much purchases of inputs or the use of more labor, with the exception of cassava seed treatment.

3. FRESH CASSAVA MARKETING IN THE NORTH COAST OF COLOMBIA

3.1 INTRODUCTION

Historically, cassava in the North coast of Colombia was mainly destined for fresh consumption. During 1981, 99% of the cassava marketed in the region was sold to the fresh market. After the introduction of the cassava drying technology in 1981, the percentage of cassava sold to the fresh market has been decreasing and in 1991, only 92% of the cassava marketed was destined for fresh consumption. Even though a lower percentage of the production was destined for fresh consumption in 1991, cassava's most important use in the region is still for fresh human consumption.

Cassava has some special characteristics which influence its marketing conduct. The crop can be stored in the ground over a relatively long period of time without a significant loss of quality, but deteriorates within three days after harvesting. Janssen (1986), states that the seasonal variation of prices, the market organization, and the cassava marketing margins, reflect the pressure to transfer the product rapidly to the final consumer.

Fresh cassava trade is carried out by a number of traders each of whom perform different functions in the marketing channel. There are three types of cassava traders in the North coast of Colombia: a) rural assembly agents, who buy cassava at the farm gate and sell to another trader, b) wholesalers, who collect cassava at the market from farmers or other traders and sell the cassava to another traders, and c) retailers, who buy cassava from traders and sell the product to the final consumer.

An analysis of the producer and consumer prices for fresh cassava shows that marketing margins in the North coast of Colombia are extremely high. Fresh cassava prices in Barranquilla, the most important urban area of the region, are on average 300% higher than farm-gate prices. In the case of Sincelejo, an important intermediate urban area, fresh cassava prices are 200% higher than farm-gate prices.

Some of the conclusions of Janssen's (1986) fresh cassava marketing study of the Atlantic coast of Colombia, which are relevant to the present study, are the following:

1) The market structure for cassava consists of many small and competing traders. He found that on average, there was one assembly agent for each 75-100 farmers. In urban areas there were up to 40 wholesalers. In addition he found that there was one retailer for every 200-300 consumers.

2) Cassava buying and selling transactions, and weekly traded volumes are small and decrease in size towards the retail end of the marketing channel. The cassava marketing channel is more geared to the quick distribution of the product than to the concentration of supply and demand.

3) Investments in cassava trade are small.

4) Information in the market is scarce and informal.

5) Fresh cassava marketing margins are extremely high, but do not leave high profits to the cassava traders.

Therefore, the cassava fresh market in the North coast of Colombia is characterized by the existence of a large number of traders, who trade small volumes and can access or exit the market easily, and that individually have no influence on market conduct. The available supply and efforts to diminish root deterioration losses are the major factors that determine the price of cassava and the volumes traded. Janssen (1986), describes the market structure as being atomistic since it allows for competition, but not efficient. Some of the causes for this market inefficiency are product perishability and lack of market information and price transmission among cassava consumption and production regions.

According to economic theory, these market characteristics suggest that the supply of marketing inputs (e_m) is highly elastic. This implies that if the demand for marketing inputs increases for some exogenous change in demand or supply, the supply of marketing inputs will increase to meet this demand without a significant increase in the cost of marketing, which includes costs of transportation, packaging, labor, and deterioration.

In previous studies the elasticity of supply of marketing services (ϵ_m) was often assumed to be infinite (i.e. Alston and Scobie, 1983, and Freebairn, Davis, and Edwards, 1982). This assumption simplifies welfare analysis to the extent that the welfare of the suppliers of marketing inputs do not change when there is an exogenous change in supply or demand at any level of the market structure. Wohlgenant and Mullen (1987), found that even though the supply of marketing inputs (ϵ_m) may be high for some products, it is not perfectly elastic. In the case of fresh cassava marketing in the North coast of Colombia, it may be argued that since the market is not efficient, it does not approximate perfect competitive conditions, and therefore, the elasticity of supply of marketing services (ϵ_m) is not perfectly elastic. For this study a baseline value of 10 was selected, but the implications of a perfectly elastic supply of marketing services will also be analyzed.

In the next section, the relationships between retail supply and farm-level demand with respect to farm and retail prices, and marketing costs will be quantified and analyzed.

3.2 METHODOLOGY

The analysis of the cassava marketing parameters will be done by using two different, but related and in some way complementary, methodologies. Two methodologies were selected for the analysis of the fresh cassava market in order to validate the estimation of the parameters, complement the results, and obtain alternative parameter values for the sensitivity analysis of the welfare analysis. The first methodology used in the study, is by George and King (1971), in which the estimation of the farm-level derived price-elasticity of demand (η_{cf}) is made by analyzing marketing margins. The second methodology is a more recent one developed by Wohlgenant (1989), which uses a system of equations in order to develop a conceptual and empirical framework on retail-to-farm demand linkages similar to the framework provided for consumer demand and producer supply interrelationships. These estimates of demand interrelationships for cassava output are important in providing linkages between retail and farm prices so that the effects of changes in retail demand, farm product supplies, and costs of marketing on retail and farm prices can be estimated.

3.2.1 George and King Methodology

3.2.1.1 **Analysis of Marketing Margins**

Marketing margins, which often include the payments for marketing services such as assembly of raw materials from the farm, processing, storage, transportation, wholesaling, and retailing, can be determined as a constant percentage spread, an absolute spread, or a combination of both. The constant percentage spread assumes that marketing margins are a percentage of prices at the farm level or at the retail level, and the absolute spread adds a specific amount (like a mark-up) to the farm-level price to obtain the retail price. George and King (1971), state that although marketing margins can be assumed to be a constant percentage spread or a absolute spread in certain situations, it seems more appropriate to assume that price spreads are determined as a combination of percentage and absolute margins. Dalrymple (1961), points out that wholesalers appear to use a constant percentage markup and retailers appear to make use of an absolute margin so that when the market is considered to be a combination of wholesalers and retailers, it may be appropriate to consider margins as a combination of these two approaches.

In order to determine how the marketing margin is determined for the case of cassava in the North coast of Colombia, the approach taken by George and King (1971) will be used.

When the margin is assumed to be a constant percentage of the retail price, $M = k*PF$ (let M denote the margin, PF the fresh cassava retail price, and k the percentage of the retail price), then

(3.1) $PF = PC + k*PF$

or

(3.2) $PC = (1-k)*PF$

where PC is the farm-gate cassava price. On the other hand, when the simplest case of an absolute marketing margin, which assumes a fixed quantity as the margin (M^o), is suggested,

(3.3) $PF = PC + M^o$.

Using George and King's (1971) specification of marketing margins

(3.4) $M = \alpha + \beta*PF$.

Since

(3.5) $PF = PC + M$

substituting equation (3.4) in (3.5), we have

(3.6) $PF = PC + \alpha + \beta*PF$

and therefore,

(3.7) $PC = -\alpha + (1 - \beta)*PF$

$PC = a + b*PF$.

where: $a = -\alpha$, and

$b = (1 - \beta)$.

3.2.1.2 **Elasticity of Price Transmission**

In order to understand how the prices at the retail level are affected by changes in the farm-gate price, the elasticity of price transmission will be estimated by using the results from the function of the relationship between farm and retail prices estimated in the previous section. According to George and King (1971), the elasticity of price transmission (τ) is calculated with the following formula:

(3.8) $\tau = (\delta PF/\delta PC)*(PC/PF) = (1/(1 - \beta))*(PC/PF)$.

For special cases were $\beta = 0$ and $\alpha = M$, the marketing margin is determined only by an absolute spread (M), the elasticity of price transmission is

(3.9) $\tau = PC/PF = PC/(\alpha + PC)$.

3.2.1.3 **Derived Farm Level Price Elasticity of Demand**

According to George and King (1971), the elasticities at one level of the marketing system can be derived from a knowledge of the elasticities at another level. They show that the price-elasticity of demand at the farm level (η_{cf}) is the product of the price-elasticity of demand at the retail level (η_r) and the elasticity of price transmission (τ). Therefore,

(3.10) $$\eta_{cf} = \tau * \eta_r.$$

3.2.1.4 **Elasticity of Substitution Between Farm and Marketing Inputs**

The conventional approach has been to assume that farm and marketing inputs are used in fixed proportions and therefore no substitution between these two groups of inputs is possible. Most of the literature concerning derived demand and price spread behavior is based on this assumption and according to Mullen, et. al (1988), this assumption has been made in part for reasons of convenience. They also point out that an even limited amount of substitution markedly alters the distribution of surplus gains between producers and consumers.

If we can assume that the price-supply elasticity of the farm output is zero (see results on supply elasticities in the section on cassava production), the elasticity of substitution between farm and marketing inputs (σ_{fm}) can be estimated by using the following formula, derived by Wohlgenant (1989) from Muth's (1964) equation for the elasticity of derived demand for farm output,

(3.11) $$\sigma_{fm} = (-\eta_{cf} + Sc*\eta_r)/(1-Sc)$$

where: Sc is the farmer's share of the retail dollar (Sc = QC*PC/QF*PF)

Gardner (1975) criticized the methodology used by George and King to estimate farm-level derived demand elasticities by demonstrating that no fixed percentage rule, a fixed absolute margin, or a combination of the two can accurately explain the relationship between farm and retail prices. He suggests that this approach can only be valid when a fixed proportion for farm and marketing inputs is assumed, which implies that the elasticity of substitution between farm and marketing inputs (σ_{fm}) is zero. Therefore, the approach of estimating the derived farm elasticity of demand by multiplying retail elasticities by the elasticities of price transmission is only correct if input proportions are fixed.

3.2.2 Wohlgenant Methodology

According to Wohlgenant (1989), the food marketing sector produces many different products from any given raw material, therefore opportunities for substitution between marketing services and raw food quantities appear to exist. In order to estimate the cassava marketing sector's supply/demand structure without direct information on retail quantities, the model developed by Wohlgenant (1989) will be used.

By assuming that elasticities are approximately constant the following system of equations is estimated:

(12) $\Delta \ln PF = AF0 + AFZ^{*}\Delta \ln Z + AFW^{*}\Delta \ln W + AFC^{*}\Delta \ln QC + \mu F$

(13) $\Delta \ln PC = AC0 + ACZ^{*}\Delta \ln Z + ACW^{*}\Delta \ln W + ACC^{*}\Delta \ln QC + \mu C$

where:
- PF = cassava retail price,
- PC = farm-level cassava price,
- QC = quantity of cassava supplied on the farm,
- Z = an exogenous retail demand shifter,
- W = an index of marketing input prices in fresh cassava marketing,

μF and μC denote random disturbance terms, and AF0 and AC0 are intercept values which reflect changes in prices solely due to trend.

The homogeneity restriction is imposed by deflating all nominal values by the consumer price index.

According to Wohlgenant (1989), the specification of the form of Z is particularly important in order to make the parameter estimates of (3.12) and (3.13) internally consistent with the consumer demand estimates. He defines the change in lnZ as

$$\Delta \ln Z = \Sigma \eta_{fs} {*} \Delta \ln PS + \xi_f {*} \Delta \ln Y + \Delta \ln POP \tag{3.14}$$

where:

η_{fs}	=	the cross-price elasticity of demand for fresh cassava with respect of the price of its substitutes,
ξ_f	=	the income elasticity of demand for fresh cassava,
Y	=	income per capita,
POP	=	total consuming population.

In order to estimate the values of Z, it is necessary to use internally consistent demand elasticities estimated from previous research.

The elasticities of retail supply and farm-level demand can be estimated if the values of the retail demand elasticities are known. The estimates of the elasticity of retail supply with respect to retail price (e_f), the elasticity of retail supply with respect to farm price (e_{fcf}), the elasticity of retail supply with respect to marketing costs (e_{fm}), the elasticity of farm-level demand with respect to retail price (η_{cff}), the elasticity of farm-level demand with respect to marketing costs (η_{cfm}), the elasticity of farm-level demand with respect to farm price (η_{cf}), and the retail-farm price transmission ($1/\tau$) can be estimated, according to Wohlgenant (1989), by using the following expressions:

$$e_f = \eta_f + (ACC{*}\eta_{fz})/B \tag{3.15}$$

$$e_{fcf} = -AFC/B \tag{3.16}$$

$$e_{fm} = (AFC{*}ACW - ACC{*}AFW)/B \tag{3.17}$$

(3.18) $\eta_{cf} = AFZ/B$

(3.19) $\eta_{cff} = -ACZ/B$

(3.20) $\eta_{cfm} = (ACZ*AFW - ACW*AFZ)/B$

where: $B = AFZ*ACC - AFC*ACZ$

η_f = the elasticity of retail demand with respect to retail price,

η_{fz} = the elasticity of retail demand with respect to Z.

According to Wohlgenant (1989), estimates of the elasticity of substitution between farm and marketing inputs (σ_{fm}) can be obtained from the equation for the elasticity of derived demand for farm output, which in view of Muth equations, in the special case where the supply elasticity of the farm output is zero, can be written as

(3.21) $\eta_{cf} = -(1 - Sc)\sigma_{fm} + Sc*\eta_f$

where: Sc is the farmer's share of the retail dollar (Sc=QC*PC/QF*PF).

Therefore, for given values of η_{cf}, Sc, and η_f, the elasticity of substitution can be computed as

(3.22) $\sigma_{fm} = (-\eta_{cf} + Sc*\eta_f)/(1 - Sc).$

Another parameter, which is the elasticity of price transmission between retail and farm prices ($1/\tau$), can be estimated according to Wohlgenant (1989) as follows:

(3.23) $1/\tau = AFC/ACC.$

3.3 EMPIRICAL FINDINGS

3.3.1 Results of the Estimations with George and King Methodology

Using 1975-91 annual data on consumer prices reported by DANE (Departamento Administrativo Nacional de Estadística) in Colombia and producer prices obtained from INCORA, equation (3.7) was fitted. The results for five major cities in the North coast of Colombia are reported in Table 3.1.

Table 3.1.--Parameter Estimates for the Relationship Between Farm and Retail Prices of Cassava in the North coast of Colombia, 1975-1991.

City		Intercept	PC[a]	R^2[b]
North coast Urban Area		14.77	0.07	0.16
		(6.55)	(1.69)	
Metropolitan urban areas	Barranquilla	14.99	0.06	0.19
		(7.43)	(1.86)	
	Cartagena	15.85	0.05	0.14
		(6.96)	(1.59)	
Intermediate urban areas	Santa Marta	6.45	0.13	0.14
		(1.75)	(1.56)	
	Montería	6.41	0.17	0.20
		(1.80)	(1.91)	
	Sincelejo	6.37	0.21	0.15
		(1.85)	(1.80)	

[a] PC = Farm-gate price ($/Kg)

[b] R^2 = Coefficient of Determination R^2

[c] t-Statistics are in Parentheses

For the urban area, both slope and intercept are significantly different from zero at $\alpha=0.05$ and $\alpha=0.001$, respectively. Therefore, the price spread between producer and consumer prices for cassava in the region are determined as a combination of percentage and absolute margins. When the function is estimated for the five major cities separately, we can see some differences. Cassava prices in Barranquilla, the most important metropolitan area in the region, are the ones that better explain the behavior of producer prices (the function estimated with Barranquilla consumer prices is the one with the highest R^2). The intercept is significantly different from zero for all the cities at $\alpha=0.001$ for Barranquilla, Cartagena, and at $\alpha=0.05$ for Santa Marta, Montería, and Sincelejo. The slope coefficient is also significantly different from zero for Barranquilla, Montería, and Sincelejo at $\alpha=0.05$ and for Cartagena and Santa Marta at $\alpha=0.10$. These results show that the margin is determined by a combination of percentage and absolute margins.

Although the margin in metropolitan and intermediate urban areas is a combination of a percentage and absolute margins, the absolute margin in intermediate urban areas is lower than in metropolitan urban areas. This marketing margin difference can explain the lower cassava price levels and higher absolute consumption levels in intermediate urban areas. On the other hand, intermediate urban areas show a higher percentage margin than metropolitan urban areas. These results, to a certain extent, can be explained by earlier findings of Janssen (1986). He found that rural cassava marketing channels are less complicated than the urban ones. In rural areas retailers or even consumers might buy directly from farmers and as the region are more urbanized rural assembly agents and wholesalers enter the marketing channel.

Estimates of the retail price-elasticity of demand for cassava (η_{rf}), the farmer's share of the retail dollar (Sc), the elasticity of price transmission (τ), the farm-level derived price-elasticity of demand of cassava (η_{cf}), and the elasticity of substitution between farm and marketing inputs (σ_{fm}) for the North coast region of Colombia and five major cities in the region are reported in Table 3.2.

These results show that even though the demand for cassava at the retail level is inelastic (meaning that a change in price will cause a less than proportional change in demand), the demand for cassava at the farm level (η_{cf}) for the whole North coast region is elastic (a change in the producer price causes a more than proportional change in the demand). The farm-level price-demand elasticity is higher for the product that goes to metropolitan urban areas (Barranquilla and Cartagena) than for the product that goes to intermediate urban areas (Santa Marta, Montería, and Sincelejo). The derived price-elasticity of demand for cassava that goes to Montería and Sincelejo (both intermediate urban areas) is inelastic, but higher than the retail price-elasticity of demand for fresh cassava in these two cities. In general, for the North coast region of Colombia, an increase in the producer price of 1% will cause a decrease in cassava farm-level demand of 2.4%.

Table 3.2.--Estimates of Farm-level Derived Demand, Price Transmission, and Substitution of Cassava in the North coast of Colombia at the Sample Means, 1980-1991

Region		Elasticity Estimates				
		η_r[a]	Sc[b]	τ[c]	η_{cf}[d]	σ_{fm}[e]
North coast Urban Area		-0.64	0.26	3.76	-2.41	3.03
Metropolitan urban areas	Barranquilla	-0.64	0.25	4.21	-2.69	3.38
	Cartagena	-0.64	0.26	5.04	-3.23	4.14
Intermediate urban areas	Santa Marta	-0.64	0.26	1.64	-1.05	1.19
	Sincelejo	-0.38	0.34	1.61	-0.61	0.73
	Montería	-0.38	0.33	1.59	-0.60	0.77

[a] η_r = retail price-elasticity of demand for cassava (estimated in the section on fresh-cassava consumption)

[b] Sc = farmer's share of the retail dollar (QC*PC/QF*PF)

[c] τ = elasticity of farm-retail price transmission

[d] η_{cf} = derived farm-level price-elasticity of demand for cassava

[e] σ_{fm} = elasticity of substitution between farm and marketing inputs

The elasticity of farm-retail price transmission (τ) is elastic and relatively high for the case of cassava in the North coast of Colombia. The farm-retail elasticity of price transmission to metropolitan urban areas is higher than the farm-retail elasticity of price transmission to intermediate urban areas, as expected. The farm-retail price transmission for the North coast of Colombia is 3.8, meaning that an increase of 1% in the producer price will cause a 3.8% increase in the retail prices. It should be noted that the elasticity of farm-retail price transmission (τ) is higher for metropolitan urban areas than for intermediate urban areas. For example a 1% increase in the cassava producer price, will be reflected in a 4.2% increases on retail fresh cassava prices in Barranquilla, while only will be reflected in a 1.6% increase on retail fresh cassava prices in Sincelejo or Montería.

Again the elasticity of substitution between farm and marketing inputs (σ_{fm}) is higher for the cassava that goes to metropolitan urban areas (Barranquilla and Cartagena) than for the cassava that goes to intermediate urban areas. The elasticity of substitution for the whole region is 3, meaning that if the price of cassava on the farm increases by 1% in relation to the costs of marketing, the use of marketing inputs will increase by 3% in relation to the quantity of cassava on the farm used. The elasticity of substitution between farm and marketing inputs (σ_{fm}) is higher when the product goes to metropolitan urban areas than when it goes to intermediate urban areas. For example, a 1% increase in the cassava producer prices relative to the cost of marketing services, will increase by 3.4% the use of marketing inputs in relation to the quantity of on-farm cassava used, when the product goes to Barranquilla; but will only increase the use of marketing services in relation to the quantity of on-farm cassava used by 0.73, when the product goes to Sincelejo.

3.3.2 Results of the Estimations with Wohlgenant Methodology

Farm output data was taken from annual publications of the Colombian Ministry of Agriculture (Anuario Estadístico del Sector Agropecuario). Time series on producer prices were obtained from CECORA, retail prices and the consumer price index to correct prices for inflation were obtained from the Monthly Statistical Bulletin of DANE. Data on population comes from the DANE publication, "Estadísticas Municipales de Colombia, 1990". The marketing cost variable is an index that was calculated based on Janssen (1986) findings on the structure of fresh cassava marketing costs. He found that labor is the most important marketing margin component and accounts for 35% of the marketing costs; transport costs are the second most important component followed by deterioration which represent 15% and 14% of marketing costs, respectively. According to these findings the cost of marketing index was calculated from time series on transport costs, obtained from COLFECAR (Federación Colombiana de Transportadores de Carga por Carretera); labor, which comes from the regional agricultural daily wages reported by DANE; packing material, are "fique" (sisal cord) sack prices collected from cassava production costs reported by INCORA; and cassava fresh consumer prices in the North coast, calculated from the prices reported by DANE, was used as a proxy for the deterioration costs. Fresh cassava prices were used as a proxy for the cost of deterioration because the amount of product that deteriorates in the marketing channel is wasted, and therefore, the market agent do not get pay for that product. If data would have been available for the price paid for the deteriorated product, which can be used for purposes other than fresh human consumption, the cost of deterioration could be calculated more accurately by subtracting this price from the fresh cassava consumer price. The consumer demand elasticities for the construction of the retail demand shifter variable come from the estimations of fresh cassava consumer demand on this study, reported in the section on fresh cassava consumption in the North coast of Colombia.

Seemingly Unrelated Regression (SUR) estimates of equations (3.12) and (3.13) without imposing symmetry and constant-returns-to-scale restrictions are displayed in Table 3.3. The parameter estimates are consistent with prior expectations. The retail demand shifter, measured by $\Delta \ln Z$, has a positive effect in both farm and retail prices and is important in determining them, but especially in determining retail prices. Farm output has a negative effect on farm and retail prices, but the effect on retail prices is not significantly different from zero. The marketing cost index has a positive and significant effect on retail prices ($\alpha = 0.01$) of fresh cassava as expected, but its effect on farm price is not significantly different from zero, implying that any decrease on marketing costs, caused by technological change or other factors, will decrease retail fresh cassava prices benefiting fresh cassava consumers, but will have no effect on farm cassava prices.

Estimates for the structural retail supply and farm-level demand elasticities, given values for the retail demand elasticities, are reported in Table 3.4.

Table 3.4.--Unrestricted Reduced-Form Econometric Estimates of Retail and Farm Product Prices, 1975-1991.

Product Price	Elasticity of Price with Respect to					
	Farm Quantity (QC)	Index of Marketing Cost (W)	Retail Demand Shifter (Z)	Intercept	R^2 [a]	DW[b]
Retail	-0.002	0.921	1.030	-0.029	0.62	2.75
	(-0.019)[c]	(3.275)	(3.793)	(-0.909)		
Farm	-0.344	0.218	0.678	-0.015	0.33	1.92
	(-1.740)	(0.425)	(1.370)	(-0.252)		

[a] R^2 = Coefficient of Determination

[b] DW = Durbin Watson Statistic

[c] t-Statistics are in Parentheses

The quantity of cassava supplied at the retail level is mainly affected by the cost of marketing. The results show that a decrease in the costs of marketing of 1%, will increase the quantity of cassava supplied by 0.89%. The effect of consumer prices on cassava retail demand is smaller than one and only significantly different from zero at $\alpha=0.50$. This result reflects the elasticity of supply of cassava at the farm-level that was found to be 0.30 for the North coast Region and not significantly different from zero at a high confidence interval.

On the other hand, the quantity of cassava demanded at the farm level is highly responsive to farm and retail prices. The elasticity of demand for cassava at the farm-level with respect to farm prices estimated by the Wohlgenant methodology (-2.8) is similar to the one estimated following the George and King methodology (-2.4), meaning that an increase in producer prices of 1% will reduce the farm-level demand of cassava between 2.4 and 2.8%.

The demand of cassava at the farm is also affected by changes in the retail price, the results show that an increase in the retail prices of 1%, will reduce the demand for cassava at the farm by 1.9%. The cost of marketing does not seem to significantly affect the farm-level demand for cassava. This could be explained to a certain extent, by the fact that changes in the cost of marketing do not affect the farm level cassava prices, and therefore, should have no effect on the demand for cassava on the farm.

Table 3.4.--Elasticity Estimates of Retail Supply and Farm-Level Demand for the North coast of Colombia.

	Elasticity Estimates	t-Statistic
Elasticity of retail supply with respect to retail price (e_r)	0.37	1.01
Elasticity of retail supply with respect to farm price (e_{fd})	0.006	0.019
Elasticity of retail supply with respect to marketing costs (e_{fm})	-0.89	-1.74
Elasticity of farm-level demand with respect to farm price (η_{cf})	-2.90	4.31
Elasticity of farm-level demand with respect to retail price (η_{crf})	-1.91	-2.14
Elasticity of farm-level demand with respect to marketing costs (η_{cfm})	1.12	0.82
Elasticity of substitution between farm and marketing inputs (σ_{fm})	3.66	10.27
Elasticity of retail-farm price transmission ($1/\tau$)	0.006	0.019

Since the elasticity of substitution between farm and marketing inputs depends on the farm-level price-elasticity of demand, and the estimated elasticity is similar with both methodologies, the estimated elasticities of substitution also take similar values. The estimated elasticity of substitution between farm and marketing inputs are quite large (3.7 and 3.0 whether the methodology of Wohlgenant or George and King is used, respectively), suggesting that substantial opportunities for substitution between marketing services and raw quantities of cassava at the farm appear to exist.

3.4 CONCLUSIONS ON FRESH CASSAVA MARKETING

The demand for cassava at the farm level is mainly affected by cassava farm and retail prices, but in general, the response of farm-level demand for cassava to changes in producer prices is higher than the response of retail demand for fresh cassava to retail price changes. The higher price demand elasticity for cassava at the farm level is related to the relatively high elasticity of farm-retail price transmission. Therefore, small changes in prices at the farm level are reflected in large price changes at the retail level. This large change in fresh cassava prices at the retail level, in turn, causes a large change in the demand for fresh cassava at the retail level, which is reflected in a large change in the demand at the farm level. Therefore, the market observes a small change in price at the farm level, reflected in a large change in the demand for cassava at that level. The relatively high farm-retail cassava price transmission, especially to metropolitan urban consumer areas, shows that the fresh cassava marketing channel does not absorb price fluctuations at the farm level, but reinforces them.

Another characteristic of the fresh cassava market, is that there seems to exist substantial opportunities for substitution between on-farm cassava and marketing inputs. One example of substitution possibilities between on-farm cassava and marketing inputs, is that it is possible to buy less cassava on the farm, but use a faster, probably more expensive, means of transportation. In this case, the same quantity of fresh cassava will reach the consumer than if more cassava is bought on the farm but slower, probably less expensive, transportation is used. This substitution between on-farm cassava and transportation inputs, explains that the market agent will accept that some of the product will deteriorate in the marketing channel as far as on-farm cassava is relatively less expensive than the use of a faster transportation mean, that will reduce the deterioration of the product.

Even though, the fresh cassava market behaves as a competitive market, since there are a large number of traders who trade small volumes of cassava and that can easily enter or leave the market, there seems to be no obvious improvement of the fresh cassava market efficiency in the North coast of Colombia over the last eight years. As concluded before by Janssen (1986), there are still big differences in the price of fresh cassava between regions, (i.e. fresh cassava prices is Barranquilla are 34% higher than in Sincelejo) suggesting that there is lack of information and price transmission among cassava consumption regions, and therefore the market is inefficient. This lack of efficiency in the fresh cassava market, suggest that it does not approximate perfect competitive conditions. Therefore, the elasticity of supply of marketing inputs in the trade of fresh cassava is elastic, but not infinite as assumed by many previous studies.

In terms of the supply of fresh cassava, the quantity of cassava supplied at the retail level is mainly affected by the cost of marketing, but does not show a strong response to changes on fresh cassava retail prices and on-farm cassava prices.

The estimation of the fresh cassava market parameters by using the two alternative methodologies (George and King, and Wohlgenant), are similar and not significantly different from each other. Therefore, the two alternative methodologies chose for the analysis of the fresh cassava market system are not exclusive, but complementary.

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cassava producers in the region. The processing costs in the experimental phase showed that the fixed costs represented only 4.2 and 2.3% of total costs for plants with a drying floor of 500 and 1,000 m^2, respectively. The principal component of the variable costs was the raw material (cassava roots), which represented 95% of total variable costs. The second most important component was labor, followed by fuel, which accounted for 3.8 and 0.3% of the total variable costs, respectively.

2. **The demonstrative or semi-commercial phase (1982-83).** By 1983, there were seven associations of small cassava farmers, which produced 946.3 MT of dry cassava and demanded 2,395.2 MT of cassava roots on the farm. Cassava demand in 1983 represented 0.6 and 1.0 % of the total cassava produced and commercialized, respectively in that year. Processing costs of the seven plants in 1983 show that average fixed costs accounted for 3.9% of total costs and ranged between 2.4 and 6.3%. Cassava accounted for 89% of the total variable costs on average and varied from 82.2 to 92.4%. Labor costs represented 6.6% of variable costs and ranged between 3.9 and 8.9%.

3. **The replication or commercial phase (1984 to present).** In 1991, approximately 142 drying plants were in operation in the North coast of Colombia. From the 142 plants, 97 were owned by small cassava producer associations, and the remainder 45 plants, were exploited on a commercial basis. During 1991, these drying plants produced around 25,000 MT, which implied a demand of 62,500 MT of cassava roots. The demand for cassava by the drying plants represented in 1991 6.6% of the total cassava produced in the region, and 8.6% of the cassava commercialized. Processing costs for some of the drying plants in 1991, show that cassava, the raw material, accounted on average for 91% of the total variable costs and the rest of the variable costs (9%) were mainly labor.

Since the beginning of the 1980s, many publications have appeared about dry-cassava processing in the North coast of Colombia (Janssen, 1986; Lynam, 1986; Cock et. al, 1990; Janssen and Lynam 1990; Perez-Crespo, 1991; Romanoff, 1991; Bode, 1991; Best et. al, 1991; Wheatley, 1991; Brekelbaum, 1992; etc.), but the response of input demand to input and output price changes and the response of output supply to dry cassava price changes have never been investigated. As such, the main objective of cassava producers in the region. The processing costs in the experimental phase showed that the fixed costs represented only 4.2 and 2.3% of total costs for plants with a drying floor of 500 and 1,000 m^2, respectively. The principal component of the variable costs was the raw material (cassava roots), which represented 95% of total variable costs. The second most important component was labor, followed by fuel, which accounted for 3.8 and 0.3% of the total variable costs, respectively.

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4.2 METHODOLOGY

4.2.1 Dried Cassava Processing Cost Function Model

The translog cost function was selected for obtaining estimates of the effect of changes on output and input prices, on input demand and substitution possibilities in the dry-cassava industry. The translog cost function was proposed as an approximation to unknown cost or production functions. It is appropriate because it does not impose stringent conditions on the parameters. A detailed discussion of the advantages of using the cost function approach over the estimation of a profit and/or a production function can be found in Binswanger (1974). A review of other studies that used the translog cost function can be found in Section 3.2.2.

We assume that the dry-cassava industry has the following production function,

(4.1) $$Qd = f(Qcd, Qp)$$

where:
- Qd = quantity of dry-cassava produced,
- Qcd = quantity of cassava,
- Qp = quantity of processing services.

According to the cost structure of the dry-cassava industry, it follows that most of the variable costs of processing, after the cost of cassava is subtracted, are represented by labor costs. Therefore, a proxy for Qp could be the quantity of labor used in the dry-cassava processing.

We also assume that the dry-cassava industry shows the following cost function,

$$(4.2) \qquad Cd = Cd(Qd, Pcd, Pp)$$

where:

Cd = cost of dry-cassava processing.

Pcd = price of the cassava roots paid by the dry-cassava industry,

Pp = the price of processing costs (a proxy of this price will be day-labor wages).

According to Ray (1982), the cost function for the dry-cassava industry in its trans-logarithmic form is the following:

$$(4.3) \qquad lnCd = a0 + ad*lnQd + add*(lnQd)^2 + bcd*lnPcd + bp*lnPp + 1/2*bcdcd*(lnPcd)^2 + 1/2*bcdp*(lnPcd*lnPp) + 1/2*bpp*(lnPp)^2 + 1/2*bpcd*(lnPp*lnPcd) + bcdd*(lnPcd*lnQd) + bpd*(lnPp*lnQd)$$

This translog (dual) cost function can be regarded as a quadratic approximation to the unspecified "true" cost function. In this context,

$$(4.4) \qquad bcdp = bpcd$$

Ray (1982) points out that one problem with multi-input cost functions is that, even for a few inputs, the number of parameters to be estimated is large. Moreover, with time-series observations needed for so many variables, it is likely to encounter severe multicollinearity problems and the estimation of the cost-function as a single-equation model may be either impossible or inappropriate. Therefore, estimating the full dual system (the cost and share equations together) is more efficient and compensates for the information inadequacy in equation (4.3) alone.

Assuming that processors choose a cost minimizing combination of factors, and differentiating equation (4.3) using Shephard's lemma gives the following cost share equations:

$$(4.5) \qquad Scd = bcd + bcdcd*lnPcd + bcdp*lnPp + bcdd*lnQd$$

(4.6) $Sp = bp + bpp*lnPp + bpcd*lnPcd + bpd*lnQd$

where: $Scd = (Pcd*Qcd)/Cd$

$Sp = (Pp*Qp)/Cd$

In order for the trans-logarithmic cost function to be linearly homogeneous in input prices, the cost function model has to include the following restriction.

(4.7) $bp = (1\text{-}bcd)$.

Based on the parameters estimated with the cassava drying-industry cost-function, the own-price and cross-price elasticities of demand for inputs (η_{ii}, η_{ij}), the Allen partial elasticity of substitution between cassava roots and processing services (σ_{fp}), which are mainly labor, and the price-supply elasticity of dried cassava can be estimated according with the derivations showed in Section 3.2.2.

4.2.2 Dried Cassava Supply Function

A dried cassava supply function can also be estimated as a function of the price of inputs and the price of the output. This approach for estimated dry-cassava supply, permits the estimation of the own-price elasticity of supply of dried-cassava (ϵ_d) without assuming marginal cost pricing for the output. Therefore, the dried cassava supply function is specified as,

(4.8) $Qd = f(Ps, Pcd, Pp)$

Since the best fitting functional form could not be determined a priori, the dry cassava supply function was estimated by using three different functional forms (linear, semi-logarithmic, and double-logarithmic), and the best fitting function was selected for further analysis. The estimated own-price elasticity of supply of dried cassava with the two alternative methodologies, with and without the assumption of marginal cost pricing, are compared. Additionally, the elasticities of supply of dried cassava with respect to the price of cassava roots and processing services (e_{dcd} and e_{dp}, respectively) were estimated.

4.3 EMPIRICAL RESULTS

4.3.1 Results from the Estimation of the Dry-Cassava Processing Cost Function

The translog cost function was estimated with annual time series data obtained from the DRI-CIAT Cooperative Project on Agro-Industrial Development of Cassava in the Atlantic coast of Colombia Annual Reports (1981-91). The estimated parameters of the translog cost function system (equations 4.3, 4.5, and 4.6), with restrictions (4.4) and (4.7), are reported in Table 4.1.

Table 4.1.--Estimated Coefficients of the Translog Cost Function, 1981-1991.

Parameter	Value	t-Statistic
A0 (intercept)	0.13217	1.13
AD	0.04160	1.86
ADD	-0.00020	-1.31
BP	0.08522	9.23
BPP	0.00338	1.18
BPD	0.00150	1.95
BCDD	-0.00490	-2.34

The parameters estimated by the translog cost function do not have a clear economic meaning, but as could be expected the cost of processing dried cassava is mainly explained by the price of inputs and quantity produced. The interactions between the quantity of dried cassava produced and the price of the factors of production are also important in explaining the costs of processing dried cassava. According to Section 3.2.2, the estimated parameters of the cost function can be used to estimate the own-price elasticities of demand of cassava (η_{cd}) and processing services (processing labor) (η_p), the cross-price elasticities of demand for cassava roots with respect to the price of processing services (η_{cdp}) and for processing services with respect to the price of cassava (η_{pcd}), and the elasticity of substitution between cassava and processing services σ_{fp}. By assuming marginal cost pricing for the outputs, the elasticity of supply of dried cassava (ε_d) can also be estimated. The estimated elasticities with their respective t-statistics are reported in Table 4.2.

The estimates of own-price elasticities of demand for inputs show that this demand is inelastic ($< |1|$). However, the elasticity of demand for processing labor is higher than the one for cassava roots. If the cost of processing services increases by 1%, its demand will decrease by 0.87%, but if the cost of cassava increases by 1%, its demand will only decrease by 0.08%.

The cross-price elasticities of demand show that the response to changes in the price of cassava is greater than the response to changes in the price of processing services. An increase in the price of cassava of 1%, will increase the demand for processing services by 0.87%, but an increase in the price of processing services by 1%, will only increase the demand for cassava by 0.08%.

The elasticity of substitution of 0.96, shows that the dried cassava processing industry has a production function that approximates a Cobb-Douglas production function[2]. An elasticity of substitution of 0.96, means that when the price of cassava increases by 1% relative to the price of

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[2] The Cobb-Douglas production function is widely used in economic analysis and may be expressed as,

$$Q = Ax_1^{\alpha}x_2^{\beta}$$

where Q is the output, x_1 and x_2 are the inputs, and α and β are the elasticities of supply of output with respect to input quantities. The Cobb-Douglas production function is homogeneous of degree one, the marginal product of both inputs is homogeneous of degree zero. This production function is also positively valued, increasing, and regular strictly quasi-concave over the domain x_1, $x_2 > 0$. For more details on this type of function see Henderson and Quandt, 1980.

processing services, the quantity of processing services used will increase by 0.96% relative to the quantity of cassava use by the industry.

The own-price elasticity of supply of dried cassava estimated by using the cost function approach and by assuming marginal cost pricing, shows that the supply of dried cassava is elastic ($\epsilon_d > 1$), which means that an increase in the price of dried cassava will produce a more than proportional shift in the supply of dried cassava. The estimated value for the supply elasticity, of 1.92, means that an increase in the dried cassava price of 1%, will increase its supply by 1.92%.

Table 4.2. Own-price and Cross-price elasticities of Demand for Inputs, Elasticities of Substitution between Pairs of Inputs, and Output-supply Elasticities for the Dried-Cassava Industry at the Sample Means.

Elasticity Estimate	Value	t-Statistic
Own-price elasticity of demand for processing services (η_p)	-0.87	-26.92
Own-price elasticity of demand for cassava roots (η_{cd})	-0.08	-26.92
Cross-price elasticity of demand for processing services with respect to the price of cassava roots (η_{pcd})	0.87	26.92
Cross-price elasticity of demand for cassava roots with respect to the price of processing services (η_{cdp})	0.08	26.92
Elasticity of substitution between cassava roots and processing services (σ_{fp})	0.96	26.92
Own-price elasticity of supply of dried cassava (ϵ_d)	1.92	52.23

4.3.2 <u>Results from the Estimation of the Dry Cassava Supply Function</u>

The supply of dried cassava was also estimated with annual data obtained from the DRI-CIAT Agro-industrial Cooperative Project Annual Reports (1981-91). The parameter estimates for the function of supply of dried cassava in its three different functional forms are reported in Table 4.3.

Results from the Linear and Semi-log functional forms of the model show that the supply of dry cassava is highly responsive to the price of inputs (cassava roots and processing labor), but less responsive to the price of dry-cassava. The results of the double-log functional form of the supply of dried cassava are different not only in the sign of the relationships, but also in the magnitude and degree of significance. When the supply of dried cassava is estimated with a double-log functional form, the price of cassava and the price of the output (dried-cassava) are the factors that have a larger influence in the supply of dried cassava. The results of the estimation of the supply of dried cassava using the double-log functional form, should be looked at with caution since the Durbin-Watson statistic shows that there may be a problem of serial autocorrelation. Therefore, the elasticities of supply of dry cassava will not be estimated with the results obtained from the double-log functional form.

Table 4.3.--Dried Cassava Supply Function Parameter Estimates

	Parameter Estimates[f]					
	Const.	Pd[a]	Pcd[b]	Pp[c]	R^2 [d]	DW[e]
Linear Model	28217	220	-1897	-1.38	0.70	1.95
	(1.09)[f]	(0.85)	(-2.10)	(-2.14)		
Semi-log Model	143960	8290	-31724	-10210	0.80	2.33
	(1.58)	(0.67)	(-2.80)	(-3.03)		
Double-log	15.40	9.76	-16.62	-0.41	0.80	1.79
	(0.40)	(1.88)	(-3.48)	(-0.29)		

[a] Pd = Dried-cassava Price ($/MT)

[b] Pcd = Price paid for Cassava ($/MT)

[c] Pp = Cost of Processing Dried Cassava ($/MT)

[d] R^2 = Coefficient of Determination

[e] DW = Durbin Watson Statistic

[f] t-Statistics are in Parentheses

The own-price elasticity of supply of dried cassava (e_d), the elasticity of supply of dried cassava with respect to the price of cassava (e_{dcd}), and the elasticity of supply of dried cassava with respect to the cost of processing (e_{dp}), can be estimated from the parameter estimates reported on Table 4.3, and are presented on Table 4.4.

Table 4.4.--Elasticities of Supply of Dried Cassava Estimated at the Sample Means.

Functional Form	e_d [a]	e_{dcd} [b]	e_{dp} [c]
Linear Model	2.53	-5.58	-1.93
	(0.85) [d]	(-2.10)	(-2.14)
Semi-log Model	1.76	-6.72	-2.16
	(0.67)	(-2.80)	(-3.03)

[a] e_d = own-price elasticity of supply of dried cassava

[b] e_{dcd} = elasticity of supply of dried cassava with respect to the price of cassava

[c] e_{dp} = elasticity of supply of dried cassava with respect to the cost of processing

[d] t-Statistics are in Parentheses

The estimates for the own-price elasticity of supply of dry cassava estimated by the supply function are similar to the ones estimated with the cost function approach. The semi-log function model is preferred to the linear model since the first one has a higher R^2 value. The own-price elasticity of supply of dry cassava estimated with the semi-log supply function equals 1.76, meaning that an increase of 1% in the price of dry cassava will increase its supply of 1.76%. This elasticity is similar to the one estimated with the cost function approach, which is equal to 1.92.

The response of the supply of dry cassava to changes in the farm-level price of cassava is high. An increase in farm-level cassava prices of 1%, will decrease the supply of dry cassava by 6.7%, at a significance level of $\alpha=0.001$. The response of the supply of dry cassava to changes on the cost of processing labor is also significant ($\alpha=0.001$) and high. An increase in the cost of processing of 1% will decrease the supply of dry cassava by 2.2%.

4.4 CONCLUSIONS ON DRIED CASSAVA PROCESSING

The main inputs for dried cassava processing, according to the dried cassava industry cost structure, are cassava roots and processing labor. The demand for these two inputs is inelastic, meaning that an increase in their prices produces a less than proportional decrease on the quantity demanded.

On the other hand, the supply of dry cassava with respect to its own price and the price of the inputs is elastic, meaning that an increase in the price of dry cassava and/or the price of cassava roots and processing labor, will produce a more than proportional increase and/or decrease on the quantity of dry cassava supplied, respectively. The elasticity of supply of dry cassava is more responsive to the price of the inputs than to its own price. The lower response to its own price could be related to the fact that in general, the price of dry cassava is fixed to the price of sorghum (Pd $\approx$ 0.8*Price of sorghum).

The own-price elasticities of supply of dry cassava estimated with the two alternative methodologies does not differ significantly. The dry cassava supply elasticity estimated with the cost function approach, assuming marginal cost pricing of the output, is in the range between the two elasticities of supply estimated with the dried cassava supply function.

There seems to exist possibilities of substitution between cassava roots and processing labor. The estimated elasticity of substitution between these two inputs of 0.96, shows that the dry cassava industry production function approximates a Cobb-Douglas function ($\sigma_{fp} \rightarrow 1$).

5. FRESH CASSAVA CONSUMPTION IN THE NORTH COAST OF COLOMBIA

Cassava is an important traditional food staple in the North coast of Colombia, but particularly in the rural sector and for low income people of urban areas. The root is consumed mostly for human consumption in its fresh form (cooked or fried).

During the early 1980s, the role of cassava diminished due to the urbanization process and the improvement of infrastructure, which facilitated the importation of products grown outside the region, such as potato. Janssen (1986), found that fresh cassava consumption fell strongly especially in the more urbanized areas, and that the marketing problems of the crop, which caused unfavorable retail prices in the urban areas, were responsible for that decreased consumption. According to the fresh cassava consumption survey conducted by Janssen (1986), fresh cassava consumption fell in urban metropolitan areas by 45% between 1980 and 1983. Data from the DANE Household Survey of 1985, show an additional decrease in fresh cassava consumption of 2% between 1983 and 1985. Wheatley and Izquierdo (1991), argue that the decrease in consumption, to a major extent, had been a response to the failure of cassava to make the transition from a rural to an urban staple. Its rapid post-harvest deterioration, makes it inconvenient, of poor quality, and expensive in urban areas. Most of the studies on fresh cassava consumption in Colombia and in the North coast region of the country, show that the fresh cassava consumption has an inelastic but significant response to price changes. Its consumption does not depend on income, although consumption levels and price-elasticities of demand are higher for the poor.

Socio-economic studies, as part of the Integrated Cassava Project, developed by CIAT, suggested that efforts to promote cassava production coupled with efforts to improve and open new markets would decrease and stabilize prices, which subsequently would increase production and therefore put downward pressure on retail prices, and increase fresh cassava consumption. The objective of this section of the study is to measure and analyze the actual fresh cassava consumption and compare it with consumption figures for the 1980s, in order to test the hypothesis that broadened markets would indirectly increase fresh cassava consumption.

In order to measure and analyze actual fresh cassava consumption, a household survey was conducted in three representative cities of the North coast of Colombia (Barranquilla, Santa Marta, and Sincelejo). These three cities were selected on the basis of differences in urbanization and behavior of fresh cassava consumer prices in the last 20 years in these cities.

Barranquilla is the most important metropolitan area of the region with an estimated population of 1,311,377 habitants in 1991. A simple regression of consumer prices on time, show that from 1970-1983 there was a tendency for prices to increase at a rate of 9.5% per year in Barranquilla, while after 1983, there was an annual tendency of prices to decrease at an annual rate of 22%.

Santa Marta, an intermediate urbanized tourist city of the region with an estimated 1991 population of 278,885 habitants, show a different price behavior than the other cities of the region. Cassava consumer prices in Santa Marta increased at an annual rate of 11.7% from 1970-1983, and after 1983, cassava consumer prices continued to increase but at a lower rate of 7.6%.

Sincelejo is also an intermediate size city located in one of the most important cassava production areas of the region, but with a lower degree of urbanization than Santa Marta and with an estimated population of 163,442 people in 1991. Cassava consumer prices in Sincelejo showed a significant decrease of 4% per year between 1970-1983, but after 1983 they remain unchanged.

The sample of the study was selected based on the DANE Socioeconomic Classification of the cities of Colombia. From the six socioeconomic groups, the four lower income groups, which account for 94% of the total population, were selected. The four groups are low-low (I), low (II), medium-low (III), and medium (IV). In each socioeconomic group, the number of blocks to be surveyed were determined based on the number of blocks in each socioeconomic group per city; and in each selected block, four homes were surveyed (one home in each face of the block)[3].

5.1 EVOLUTION OF FRESH CASSAVA CONSUMPTION IN THE LAST DECADE AND ITS RELATIVE IMPORTANCE

Table 5.1 shows that during 1983, fresh cassava consumption was lower in Barranquilla, an urban metropolitan area, than the consumption of other caloric sources such as rice, plantain, and potatoes; while in Sincelejo, an intermediate city, cassava was in third place after rice and plantain consumption. According to the 1991 fresh cassava consumption survey, the

Table 5.1.--Average Consumption of Starchy Food Crops in Barranquilla and Sincelejo, 1983 and 1991.

Food Crop	Barranquilla			Sincelejo		
	1983[a]	1991[b]	% Change	1983	1991	% Change
	Consumption (Kg per capita/year)					
Rice	69.4	54.1	-22.05	71.4	63.0	-11.76
Yam	30.5	19.3	-36.72	30.8	46.1	49.68
Potato	36.6	35.5	-3.01	35.0	31.1	-11.14
Plantain[4]	64.4	40.8	-36.65	76.6	68.7	-10.31
Cassava	30.5	40.9	34.10	53.5	75.9	41.87

[a] Source: Cassava consumption survey among purchasers and producers, CIAT, 1983.

[b] Source: Fresh Cassava consumption survey, Cassava Economics, CIAT, 1991.

[3] For a more detailed account of the sampling procedure used, see Perdomo and Henry (1992).

[4] For the case of plantain, the comparison depends on the conversion of plantain units to Kg. For purposes of this study a conversion coefficient of 0.296 Kg/unit of plantain was used, which is the average weight of different varieties of plantain.

relative importance of cassava has changed and cassava with plantains is now in second place in Barranquilla, showing the highest per capita consumption in Sincelejo, even higher than rice consumption. These results suggest that cassava has renewed its importance in the North coast's urban population nutrition. An important factor that may have influenced the increase in the relative importance of cassava in the region is the significant decrease in price of cassava relative to other starchy products, such as potato, rice, and plantain.

Table 5.2 shows that, on average, in the North coast's major cities, the price of cassava relative to the price of potato, rice, and plantain has decreased by 45, 32, and 56%, respectively. For the specific case of Barranquilla the same behavior in relative prices can be observed; but the decrease in relative cassava prices is lower. For the case of the price of cassava with respect to rice, the relative price did not change significantly. To a certain extent, this can be explained since rice is still the product with the highest per capita consumption in Barranquilla. These data suggest that cassava's relative importance in the nutrition of the people in the North coast of Colombia has improved and is reversing from its position during the early 1980s. This change in importance, in part can be explained by the change in the price of cassava substitutes. As such, this will be analyzed further in the next section of the study.

Table 5.2.--Change on the Relative Consumer Price of Cassava in the Last Decade in the North Coast Cities and Barranquilla

	Relative Price					
	North Coast Region			Barranquilla		
	1981	1991	% Change	1981	1991	% Change
Cassava/Potato	0.82	0.45	-45.12	0.85	0.56	-34.12
Cassava/Rice	0.39	0.32	-17.95	0.38	0.37	-2.63
Cassava/Plantain	1.09	0.57	-47.71	0.96	0.50	-47.92

Source: DANE, Boletín de Estadística.

Tables 5.3 and 5.4 show the evolution of cassava consumption in Barranquilla and Sincelejo. Cassava consumption in Barranquilla, reached its lowest level of 30.5 Kg per capita in 1983 after decreasing by 46% from its 1980 level. This decrease in consumption can also partly be explained by the increase in cassava prices of 22% from 1980 to 1983. After 1983, cassava consumption in Barranquilla began to increase again reaching a level of 40.9 Kg per capita in 1991, with an increase of 34% from 1983. This increase in consumption can also in part be explained by the change in prices, which decreased by 50% from 1983 to 1991. Cassava consumption in Sincelejo also reached its lowest level in 1983 after a price increase of 26% from 1980. Consumption also increase to 76 Kg per capita in 1991 as a response to a decrease on prices of 52% from 1983 to 1991.

Data on cassava consumption in Santa Marta for 1980 and 1983 do not exist, but the 1991 survey results show that cassava consumption increased from 33.3 Kg per capita in 1987 to 34.9 Kg per capita in 1991 (1.2%) after a price decrease of 31%.

Table 5.3.--Fresh Cassava Consumption and Price Evolution in Barranquilla

Year	Fresh Cassava Consumption		Fresh Cassava Consumer Price	
	(Kg per capita/year)	% Change	1988 Constant Prices ($/Kg)	% Change
1980	56.3[a]		80.92[c]	
1983	30.5[a]	-45.83	98.32	21.50
1987	39.5[b]	29.51	70.92	-27.87
1991	40.9[b]	3.54	52.54	-25.92

[a] Source: Cassava consumption survey among purchasers and producers, CIAT, 1893.

[b] Source: Fresh Cassava Consumption Survey, Cassava Economics, CIAT, 1991.

[c] Source: DANE, Boletín de Estadística.

Table 5.4.--Fresh Cassava Consumption and Price Evolution in Sincelejo

Year	Fresh Cassava Consumption		Fresh Cassava Consumer Price	
	(Kg per capita/year)	% Change	1988 Constant Prices ($/Kg)	% Change
1980	59.7[a]		63.16[c]	
1983	53.5[a]	-10.39	79.40	25.71
1987	76.4[b]	42.80	58.80	-25.94
1991	76.0[b]	-0.52	38.03	-35.32

[a] Source: Cassava consumption survey among purchasers and producers, CIAT, 1983.

[b] Source: Fresh Cassava Consumption Survey, Cassava Economics, CIAT, 1991.

[c] Source: DANE, Boletín de Estadística.

These results suggest that cassava consumption has significantly increased in the late 1980s as a response to the change in own price and prices of its substitutes. On the other hand, income per capita, according to DANE figures, increased only by 0.3% from 1980 to 1989. This suggest that there was no income effect in the increase of cassava consumption in the North Coast during the last decade. In order to better analyze the relationships between cassava consumption and cassava prices, income, prices of substitutes, and urbanization, and to validate the above results a simple regression model for cross-sectional and time-series data was constructed.

5.2 ECONOMETRIC ANALYSIS OF FRESH CASSAVA DEMAND

5.2.1 Cross-Sectional Analysis

A cross-sectional analysis of fresh cassava consumption was conducted with data obtained from a household consumption survey conducted by the Cassava Economics Section, CIAT in 1991.

In order to study the income effect on fresh cassava consumption, the households surveyed were classified by income level, according to the DANE socioeconomic classification. For each income strata, a double-logarithmic regression of cassava consumption on cassava price, the price of substitutes, and income was estimated.

Results from the estimation of the fresh cassava consumption function by income strata are reported in Table 5.5. These results show that fresh cassava consumption is higher for the low income group and decreases for higher income groups, suggesting that cassava is relatively more important for the poor than for the rich. In all income groups, the response to price is significantly different from zero; and increases in absolute terms as the income increases, but for the highest income strata group it begins to decrease again.

Table 5.5.--Income Effect on Average Cassava Consumption in the Urban North Coast of Colombia, 1991.

Income Strata	Average Cassava Consumption (Kg per capita/year)	Price-Elasticity of Demand (η_r)	Income-Elasticity of Demand (ξ_r)	Number of Observations
I (Low-low)	48.1	-0.57[c]	0.47[a]	141
II (Low)	45.3	-0.67[a]	0.29[b]	177
III (Medium-Low)	39.2	-0.90[a]	n.s.[d]	269
IV (Medium)	35.2	-0.64[c]	-0.43[a]	152

[a] $\alpha = 0.01$

[b] $\alpha = 0.05$

[c] $\alpha = 0.10$

[d] n.s. = non significantly different from zero ($\alpha > 0.25$)

The size of the estimated price-elasticity of demand for fresh cassava and their pattern of response to price changes by income group are consistent with the results obtained by Sanint, et al. in 1985. In terms of response of fresh cassava consumption to income, poor cassava consumers tend to react more to income changes than rich consumers. As people have higher incomes they tend to respond less to income changes, meaning that for the rich consumers an increase in income would not be reflected by an increase in fresh cassava consumption. For the highest income group, the effect of income on cassava consumption is negative, meaning that for the richer people cassava begins to behave as an inferior good. As income increases for that group cassava consumption will decrease.

The results of the estimation of the double-log function for fresh cassava consumption in the three surveyed cities and for the urban area of the region (represented by the three cities surveyed) are reported in Table 5.6. Data show that there are differences in fresh cassava consumption in the three cities, but the level of urbanization do not explain these differences. For example, cassava consumption is higher in Sincelejo, the less urbanized city of the three, but cassava consumption in Santa Marta is lower than the consumption in Barranquilla, which is the more urbanized city of the region. However, the different consumption levels between the three cities can be explained by the differences in cassava prices, and the prices of their substitutes. Sincelejo, the city with the highest per capita consumption, shows the lowest fresh cassava retail price. In 1991, fresh cassava prices in Sincelejo were on average 27.5 and 35.4 % lower than prices in Barranquilla and Santa Marta, respectively. On the other hand, potato prices, an important cassava substitute, in 1991 for Sincelejo were 1.98 and 6.58 % higher than potato prices in Barranquilla and Santa Marta, respectively (DANE, Boletín de Estadística). Therefore, cassava consumption in Sincelejo is higher, where cassava prices are lower and the prices of its substitutes are higher. The opposite can be shown for Santa Marta, which has the lowest per capita consumption of fresh cassava. Santa Marta is the city with the highest fresh cassava prices and the lowest substitute prices of the three cities surveyed.

Price-elasticities of demand for the three cities are significantly different from zero ($\alpha \leq 0.20$), showing that fresh cassava consumers do respond to price changes. The response to income changes vary between the three cities and can be explained by differences in average income levels. Sincelejo, the city with the lowest per capita expenditure (267,327 \$.Col per capita/year) has a positive and significant (α = 0.05) response to income changes. But as the income level of the population increases, which is the case of Santa Marta (290,558 \$.Col per capita/year), the response to income changes becomes non significant (α > 0.25). In the case of Barranquilla, the city with the higher income level (332,222 \$.Col per capita/year), cassava begins to behave as an inferior good and therefore an increase in income will be reflected in a decrease of fresh cassava consumption. The estimates with cross-sectional data do not capture any significant response of fresh cassava consumption to substitute price changes, but answers to the opinion questions show that 75.6 and 73 % of the consumers identify potato and plantain, respectively, as the most important substitute products for cassava (see Table 5.7).

Table 5.6.--Fresh Cassava Consumption in Three Cities of the North Coast of Colombia.

City	Average Cassava Consumption (Kg per capita/year)	Price-Elasticity of Demand (η_i)	Income-Elasticity of Demand (ξ_i)	Number of Observations
North Coast Urban Region	41.57	-0.71[a]	n.s.[e]	739
Sincelejo	76.4	-1.27[b]	0.56[b]	184
Barranquilla	40.9	-0.65[b]	-0.15[d]	297
Santa Marta	34.9	-0.64[c]	n.s.[e]	258

[a] α = 0.01

[b] α = 0.05

[c] α = 0.20

[d] α = 0.25

[e] n.s. = non significantly different from zero (α > 0.25)

Table 5.7. Principal Cassava Substitute Products in the Urban Area of the North Coast of Colombia

Product	Percentage of respondents that substitute this product for cassava	Number of Observations
Potato	75.6	86
Plantain	73.0	89
Rice	34.9	86
Yam	20.9	86
Bread	19.3	88
Corn	17.2	87
Noodles	16.1	87

5.2.2 Time-series Analysis

A time-series analysis of cassava consumption was also conducted for Barranquilla and Sincelejo, where it is possible to obtain biannual data on fresh cassava consumption through the different consumption surveys conducted in the city. Per capita fresh cassava consumption figures were obtained from Janssen (1986), DANE (1981 and 1985), and CIAT, Cassava Economics (1991) and regressed against consumer prices, an index of the price of substitutes (potato, plantain, and rice), and income per capita. Data on prices and income were obtained from DANE. The best fitting model was a double-logarithmic model and the results are shown in Table 5.8.

The results from the time series estimation provide additional support to the conclusion that own-price and the price of substitutes are the most important factors that explain fresh cassava consumption in the North Coast of Colombia. The impact of the level of urbanization on the demand for fresh cassava is an indirect consequence of the effect of urbanization on cassava prices, because marketing limitations of the product make it expensive in urban areas. Cassava substitute products, on the other hand, do not have the same marketing problems as cassava and therefore are relatively cheaper than cassava in urban areas, which also contributes to the negative effect of urbanization on fresh cassava consumption. It is important to clarify that urbanization does not have a direct impact on fresh cassava consumption, but has an indirect effect through its influence on retail cassava prices and the price of its substitutes.

Table 5.8.--Estimated Elasticities from Time-series Data for Fresh Cassava Consumption in Barranquilla and Sincelejo, 1980-1991.

Parameter	Barranquilla	Sincelejo
	Estimate	
Own price-elasticity of demand (η_f)	-0.64	-0.38
	(-2.27)[a]	(-1.92)
Cross-price elasticity of demand with respect to substitutes (η_{fs})	1.04	0.42
	(2.16)	(1.57)
Income elasticity of demand (ξ_f)	-1.13	-0.29
	(-1.06)	(-0.78)

[a] t-Statistics are in Parentheses

5.4 CONCLUSIONS ON FRESH CASSAVA CONSUMPTION

Three important issues can be concluded about fresh cassava consumption in the last decade. First, fresh cassava consumption per capita increased, especially for low income people, after a decrease during the early 1980s. Second, there had been a significant decrease in fresh cassava prices and in their fluctuation. And third, the price of cassava substitutes, potato and plantain mainly, increased, decreasing the relative price of cassava with respect to the price of its substitutes even more. These changes in fresh cassava consumption suggest that cassava has renewed its importance as a caloric source in the nutrition of the urban population of the North Coast of Colombia, but especially for the poor urban consumers.

The absolute level of fresh cassava consumption varies between the different cities of the region. The variation in the quantity of fresh cassava consumed among the different cities is mainly a response to differences in fresh cassava prices and the price of its substitutes, and to a certain extent, to differences in income level.

The analysis of fresh cassava consumption show that even though there is no income effect for the increase of cassava consumption over time, there are differences in the absolute level of consumption among different income groups and cities with different average income levels. Poor people tend to consume higher absolute levels of fresh cassava than rich people, but react less to price changes. Although cassava is not considered as an inferior good for poor people, once a certain level of income is reached it starts to behave as an inferior good. This means that if the income level of already rich people increases, the demand for fresh cassava will decrease, but the opposite will happen in the case of poor people.

On the other hand, fresh cassava consumption shows a significant response to changes in its own price and the price of substitutes. This response to price changes is more significant for price changes over time than for price differences at a point in time.

Even though the level of urbanization has an effect in the consumption of fresh cassava, as suggested by previous studies, the effect of urbanization is an indirect effect. Since cassava is a product with serious commercialization problems because of it rapid post harvest deterioration, its marketing is more expensive than the marketing of its substitute products. The rapid deterioration of fresh cassava makes it an expensive product in urban areas, especially when compared with the price of its substitutes. Since the price of cassava is lower in rural production areas than in urban metropolitan cities, fresh cassava consumption in urban areas is lower than in rural areas.

6. WELFARE ANALYSIS

6.1 BENEFITS OF THE ADOPTION OF CASSAVA TECHNOLOGY IN THE NORTH COAST OF COLOMBIA

6.1.1 A model of the Cassava System in the North Coast of Colombia

A model of the cassava system in the North coast of Colombia was constructed to simulate the impact of the adoption of cassava technologies in the region. This simulation is important because it allows to: (1) calculate the net benefits to society from the adoption of technology, (2) distribute the benefits from technology between producers, market agents, processors, and consumers, and (3) differentiate the benefits that are due to the establishment of the cassava drying industry, the adoption of improved production technology, and to other exogenous factors such as the land reform or the improvement of credit availability to small farmers.

The simulation model selected for this study is a linear-in-logs equilibrium displacement model, as named by Alston. These type of models were first used by Allen (1938), Hicks (1957), and Muth (1964). Most recent applications of these models are by Gardner (1975), Wohlgenant (1982), Sumner and Wohlgenant (1985), Mullen, Wohlgenant, and Farris (1988), and Alston (1990). The methodology consists of a description of the input and output equilibrium conditions of the system, which is then displaced and expressed in its log-linear form. The log-linear system of equations can then be solved so that the endogenous variables, expressed in terms of percentage changes in quantities and prices of inputs and outputs, are expressed as functions of exogenous factors, such as the elasticities of demand and supply of inputs and outputs, and the input substitution elasticities, that displace the supply and demand functions.

These type of models are very useful since they, 1) give a clear understanding of how exogenous shocks affect the system, given fundamental system parameters, 2) permit the assessment of the impact of exogenous shocks by using previous estimated parameters of the system, and 3) can be used to determine to what extent a change in equilibrium quantities and prices is due to the adoption of a technology, a policy change, or other exogenous factors that shift the supply and demand functions, in ex-post analysis.

As a response to the significant interest among economists and research funding agencies in obtaining evidence on the size and distribution of the returns to agricultural research and development, Alston (1990), developed a methodology to estimate the size and distribution of benefits in the context of multiple factors and multiple product markets. Alston's methodology also tries to separate more specifically the measure of benefits in order to allocate the "producer surplus" among the individual productive factors such as producers, market agents, and processors. Alston (1990), points out that the extension of the analysis of research benefits to a multiple market setting, may also lead to a different perspective on the implication of technical change for the total economy as well as for different groups of society.

In the case of technology impact in the North coast of Colombia, it is of interest to analyze the change in benefits from the Integrated Cassava Projects for the following groups of society: 1) fresh cassava urban consumers, 2) dried cassava consumers, mainly the feed industry and integrated poultry and pig producers, 3) dried cassava processors, which for the period of analysis were mainly associations of small cassava producers with private enterprise entering the market during the last three years, 4) fresh cassava market agents, and 5) cassava producers. It is also of interest to study the implications of technology for urban versus rural fresh cassava consumers, and for producers that adopt technology versus non-adopting producers.

At present, the cassava system in the North coast of Colombia can be visualized in two stages. Let,

Qc	=	quantity of cassava produced on the farm,
Qcf	=	quantity of on-farm cassava demanded by the fresh market,
Qcd	=	quantity of on-farm cassava demanded by the dry cassava industry,
Qm	=	quantity of marketing services,
Qp	=	quantity of processing services,

Qf = quantity of fresh cassava, and
Qd = quantity of dried cassava produced.

Also let the prices of the inputs be defined as Pcf, Pcd, Pm, and Pp, and the prices of the products be defined as Pf and Pd, respectively. In the first stage, on-farm cassava (Qc) is produced, which is an input both in the dry cassava processing industry (Qcd) and the fresh cassava marketing (Qcf). In the second stage, the dry cassava industry provides processing services (Qp), and the fresh cassava market provides marketing services (Qm), producing two different products, which are dry cassava (Qd) and fresh cassava (Qf).

The basic Alston (1990) model with two factors of production under variable factor proportions, will be used in order to calculate de total observed benefits and the benefits due to the adoption of the dry cassava technology and the cassava production technology, as well as the distribution of these benefits among the different groups of society. This basic model, is extended to include different products (fresh and dry cassava) which share one common factor of production (on-farm cassava).

According to Alston (1990) and following Muth (1964), a market equilibrium model of a competitive industry, producing a homogeneous product and using two factors of production can be described with the following six general equations:

Let, $i = f, d$; $r = cf, cd$; and $s = m, p$

(6.1) $Qi = f(Pi)$ Consumer Demand

(6.2) $Qi = f(Q_r, Q_s)$ Production Function

(6.3) $P_r = PW_r$

Factor Demand

(6.4) $P_s = PW_s$

(6.5) $Q_r = g(P_r)$

Factor Supply

(6.6) $Q_s = h(P_s)$

The endogenous variables in the model are output (Qi), the quantity of the two factors of production used (Q_r and Q_s), the output price per unit of the final product (Pi), and the factor prices (P_r and P_s). W_r and W_s are the value of the marginal product of factor *r* and *s*, respectively. When the system is shocked, for example as a result of a technical change or a change in policy, causing a small deviation from equilibrium, the changes in input and output prices and quantities can be linearly approximated by totally differentiating the system and converting them to elasticity form.

The above system of equations (6.1 - 6.6) can then be differentiated and expressed in terms of relative changes and elasticities. Therefore, the following system of logarithmic differential equations for the specific case of the cassava system in the North coast of Colombia is derived:

Fresh-Cassava Market	Dry-Cassava Market
Consumer Demand	
(6.7) $EQF = \eta_f * EPF$	$EQD = \eta_d * EPD$
Production Function	
(6.8) $EQF = Scf * EQCF + Sm * EQM$	$EQD = Scd * (EQCD - \alpha_{cd}) + Sp * (EQP - \alpha_{cd})$
Factor Demand	
(6.9) $EPCF = EPF - (Sm/\sigma_{fm}) * EQCF + (Sm/\sigma_{fm}) * EQM$	$EPCD = EPD - (Sp/\sigma_{dp}) * (EQCD - \alpha_{cd}) + (Sp/\sigma_{dp}) * (EQP - \alpha_{cd})$
(6.10) $EPM = EPF + (Scf/\sigma_{fm}) * EQCF - (Scf/\sigma_{fm}) * EQM$	$EPP = EPD + (Scd/\sigma_{dp}) * (EQCD - \alpha_{cd}) - (Scd/\sigma_{dp}) * (EQP - \alpha_{cd})$
Factor Supply	
(6.11) $EQM = e_m * EPM$	$EQP = (e_p * EPP) + \alpha_{cd}$

(6.12) $EQC = EQCF + (EQCD - \alpha_{cd}) = e_c * (Sf * EPCF + Sd * EPCD) + \beta_{cd} + \beta_{cp}$

Market Equilibrium Condition

(6.13) $EQC = EQCF + (EQCD - \alpha_{cd}) = Sf*EQCF + Sd*(EQCD - \alpha_{cd})$

where E denotes relative changes (i.e. EQF = dQF/QF = dlnQF), η_f and η_d are the elasticities of demand of fresh and dried cassava, respectively; σ_{fm} is the elasticity of substitution between farm and marketing inputs in the fresh cassava marketing; σ_{dp} is the elasticity of substitution between cassava and processing services in the dry cassava industry; and e_m, e_p, e_c are the price-supply elasticities of marketing services, processing services, and on-farm cassava, respectively.

Let us define *Sr* and *Ss* as the cost share of inputs *r* and *s* in the production of product *i* (*i=f,d*; *r=cf,cd*; and *s=m,p*), therefore,

(6.14) Sr = Pr*Qr/Pi*Qi)

(6.15) Ss = Ps*Qs/Pi*Qi), and

(6.16) Sr + Ss = 1.

Also, let *Si* be defined as the percentage of the total on-farm cassava demand for the production of product *i* (*i=f,d*), therefore,

(6.17) Si = Qr/Qc.

The exogenous shifters of the system are:

1) α_{cd} is a vertical shift in the demand of on-farm cassava for processing services by the drying industry because of the adoption by the dry cassava industry, reflecting an increase in the demand for on-farm cassava and processing services; and

2) β_{cd}, and β_{cp} are vertical shifts in the supply of on-farm cassava reflecting an increase in the supply of cassava due to the adoption of dry cassava and production technologies, respectively.

Even though, the model can be simulated with the three exogenous shifters at the same time, the model is simulated in two separate stages in order to estimate the impact of the cassava drying technology separately from the impact of the cassava production technology.

The system is first solved with a parallel shift in the demand for on-farm cassava and processing services (α_{cd}) and a parallel shift in the supply of on-farm cassava due to a decrease of the risk of cassava price fluctuations (β_{cd}), in order to estimate the impact from the adoption of the dry-cassava technology. The value used for α_{cd}, is the percentage increase in the quantity of cassava roots bought by the dry-cassava industry from 1984 to 1991 (202%). The base year of 1984 was chosen because it was not until that year that the cassava drying plants were replicated beginning the commercial phase of the project in the North coast of Colombia. The size of the shift in the supply of on-farm cassava is calculated based on the estimated Nerlove Supply Model described in sections 2.2.1 and 2.3.1.

According to the estimated results, cassava farmers are significantly influenced by the fluctuation of prices. It was found that for the whole region, a decrease in the fluctuation of price (calculated by their standard deviation) of 1% will increase cassava supply by 0.23%. Time series observations on producer prices show that the standard deviation of producer prices paid in the fresh market decreased by a 46% after 1984 (when the dry-cassava plant commercial phase began) and the standard deviation of producer prices paid by the dry cassava industry was 83% lower than the standard deviation of cassava producer prices before 1984. According to:

(6.18) $\Delta STD = (0.46^{*}Sf) + (0.83^{*}Sd) = 0.49,$

the standard deviation of prices received by the cassava farmers in the North coast of Colombia (ΔSTD) decreased by 49%.

Therefore the model is simulated for an increase of 11.26% in the supply of cassava due to a decrease of 49% in producer price fluctuations faced by the cassava producers, because

(6.19) $\beta_{cd} = 49 * 0.23 = 11.26$

The impact from the adoption of improved production technology is simulated with a parallel shift in the supply for on-farm cassava (β_{cp}). Cassava production in the North coast of Colombia increased from 404,400 MT in 1984 to 1,085,620 MT in 1991, which represent a 168% increase in production. From the total increase in cassava supply of 681,220 MT, 21.6% is due to an increase in yield and the other 78.4% is due to an increase in area planted with cassava. It is reasonable to argue that all increase in yield is a result of the adoption of improved production technology, but it will be unrealistic to say that also all the increase in area planted is a result of technological innovations. Since there are other exogenous influences regarding the increase in area, such as land reform or the improvement of credit availability to small farmers, the baseline estimates of the benefits provided by the adoption of cassava production technology, are calculated under the assumption that all yield increase and half the increase in area planted with cassava is a result of the adoption of production technology. Hence, for the baseline estimate of benefits, the model simulated a parallel shift in the supply of cassava of 100% ($\beta_{cp} = 1$). Benefits were also calculated under two different scenarios, assuming that all the increase in yield and 3/4 of the increase in area is due to the adoption of production technology ($\beta_{cp} = 1.34$) and that all the increase in yield and 1/4 of the increase in area is because of the adoption of production technology ($\beta_{cp} = 0.66$), respectively.

Linder and Jarret (1978), concluded that the total level of benefits from the adoption of a technical innovation is influenced by the nature of the shift of the supply curve. Therefore, when benefits are estimated it is important to justify the nature of the supply shift. A parallel shift in supply implies that the absolute reduction in average costs is the same for both low cost and high cost producers, meaning that the technological innovation is scale independent. For the case of the cassava supply shift in the North coast, it was already stated that 78% of this supply shift was due to an increase in area planted with cassava. Since area increases do not affect the cost structure of production, the shift in cassava supply due to an increase in area can be assumed to be of a parallel nature. For the portion of the increase in cassava supply due to an increase on yield (22%), it was found by an Adoption Survey conducted by Cassava Economics, CIAT, (1991) that most of the yield increase has been due to technology that involves cultural practices, such as increased planting density, stake selection, new varieties, and method of planting. Adoption of production technology that involves cultural practices and/or new varieties do not allow any economies of scale and therefore can also be approximated by a parallel shift in supply. It was also found that only 5 and 6% of the respondents that adopted some technology are using tractors for land preparation and herbicides, respectively. According to Linder and Jarret (1978), mechanical innovations are scale dependent and result in a convergent shift in the supply curve, while biological and chemical innovations, such as the use of herbicides, result in a divergent shift in the supply function. Since only a small percentage of the increase in cassava production is due to mechanized or chemical innovations, it seems appropriate to assume that for the case of cassava in the North coast of Colombia, the shift in the supply curve can be assumed to be of a parallel nature.

6.1.2 Surplus Measures

According to Alston (1990), the linear-in-log displaced model does not require any explicit or implicit assumptions about the functional forms of supply and demand, provided that the functions can be converted to a linear form, and it is a local approximation to unknown functions. However, in order to measure benefits for different groups of society, the following assumptions are made: 1) the supply and demand functions are approximately linear in the region of interest. 2) the shift in supply of cassava due to cassava drying and production cassava technologies (β_{cd}, β_{cp}) is parallel, and 3) based on Just et al. (1982), producer surplus is defined as the area above the supply curve and below the market price, and consumer surplus is defined as the area under the demand curve and above the market price.

Hence, under the previous assumptions, benefits accruing to fresh urban and dry cassava consumers (ΔFCS, ΔDCS), market agents (ΔMS), processors (ΔPS), and producers (ΔCPS), can be estimated as follows:

(6.20) $$\Delta FCS = -PF_0QF_0(EPF)(1 + 0.5EQF)$$

(6.21) $$\Delta DCS = -PD_0QD_0(EPS - EQS)(1 + 0.5EQS)$$

$$(6.22) \qquad \Delta MS = PM_0QM_0(EPM)(1 + 0.5EQM)$$

$$(6.23) \qquad \Delta PS = PP_0QP_0(EPP - \alpha_{cd})(1 + 0.5EQP)$$

$$(6.24) \qquad \Delta CPS = PC_0QC_0(EPY + \beta_{cd} + \beta_{cp})(1 + 0.5EQY)$$

For the first simulation of the model, to estimate the benefits from the adoption of the dry-cassava technology, $\beta_{cp} = 0$. For the second simulation of the model, to estimate the benefits from the adoption of the cassava production technology, $\alpha_{cd} = 0$ and $\beta_{cd} = 0$.

The calculation of observed benefits serves to validate the estimated model results. Therefore, observed benefits for the different groups of society in the North coast of Colombia, are also calculated by using equations (6.20) - (6.24). The percentage changes in prices and quantities of inputs and outputs are the ones calculated from observed price and quantity changes. The exogenous shifts in cassava supply and demand are also observed changes in cassava supply and demand.

6.1.3 Results of the Estimation of Benefits in the North Coast Cassava System

In order to examine the impact of the cassava drying and the cassava production technology, the model of the cassava system in the North coast of Colombia described above was used. First, the cassava system model was simulated by using the baseline values for the system parameters estimated in the previous sections of the study of cassava production, marketing, processing, and consumption. Second, a sensitivity analysis was conducted by using alternative measures of system parameters also estimated in the sections on cassava production, marketing, processing, and consumption.

6.1.3.1 Estimated Benefits from the Cassava Drying Technology Adoption

Table 6.1 shows the estimated benefits accruing to the different groups of society in the North coast of Colombia from the adoption of the dry

Table 6.1.--Baseline Solution and Sensitivity of System Parameters to Change in Accumulative Economic Surplus due to the Adoption of Cassava Drying Technology.

			FCS	DCS	MS	PS	CPS	TS
baseline estimates			232.65[h]	4,334.0	-77.76	1,149.5	1,307.0	6,945.5
system parameters								
	base value	alternat. value						
η_f^{a}	-0.64	-0.38	245.34	4,334.0	-90.83	1,204.3	1,262.3	6,955.1
			(5.45)[i]	(0.00)	(16.81)	(4.77)	(-3.42)	(0.14)
η_d^{b}	-3.18	-2.86	232.65	4,334.7	-77.76	1,149.7	1,303.4	6,942.8
			(0.00)	(0.02)	(0.00)	(0.02)	(-0.28)	(-0.04)
σ_{fm}^{c}	3.00	3.66	193.41	4,334.0	-82.12	1,149.5	1,483.0	7,077.9
			(-16.87)	(0.00)	(5.61)	(0.00)	(13.47)	(1.91)
σ_{dp}^{d}	0.96	0.86	232.65	4,334.0	-77.76	1,143.7	1,303.2	6,935.8
			(0.00)	(0.00)	(0.00)	(-0.50)	(-0.29)	(-0.14)
ϵ_m^{e}	10.00	100.00	197.65	4,334.0	-8.21	1,149.5	1,341.9	7,014.9
			(-15.04)	(0.00)	(-89.44)	(0.00)	(2.67)	(1.00)
ϵ_p^{f}	1.00	0.50	232.65	4,333.9	-77.76	1,148.4	1,303.2	6,940.4
			(0.00)	(0.00)	(0.00)	(-0.10)	(-0.29)	(-0.07)
ϵ_c^{g}	0.00	1.00	162.87	4,331.9	-54.59	1,150.7	1,649.8	7,240.6
			(-29.99)	(-0.05)	(-29.80)	(0.10)	(26.23)	(4.25)

[a] η_f = price elasticity of demand for fresh cassava

[b] η_d = price elasticity of demand for dried cassava

[c] σ_{fm} = elasticity of substitution between farm and marketing inputs

[d] σ_{dp} = elasticity of substitution between farm and processing inputs

[e] ϵ_m = price elasticity of supply of marketing inputs

[f] ϵ_p = price elasticity of supply of processing services

[g] ϵ_c = price elasticity of supply of cassava on the farm

[h] The numbers in the matrix are the changes in fresh cassava urban consumer surplus (FCS), dried cassava consumers surplus (DCS), cassava producers surplus (CPS), marketing agents surplus (MS), dried cassava processors surplus (PS), and total surplus to the society (TS) in 1991 thousand dollars.

[i] The numbers in parentheses are percentage changes from the baseline solution when the system parameters change to the alternative value. They are calculated as the new measure of surplus less the base measure as a percentage of the base measure.

cassava technology and a sensitivity analysis of these results. It was estimated that the region has had a net gain of 7 million US$ from 1984 to 1991 because of the adoption of the dry cassava technology. From this total net gain, fresh cassava urban consumers gain 0.2 millions (3.4%), dried cassava consumers (mainly feed plants and integrated poultry and pig producers) gain 4.3 million (62.4%), dried cassava processors 1.1 million (16.5%), and cassava producers 1.3 million (16.6%). On the other hand, fresh cassava intermediaries lost only 78 thousand US$.

6.1.3.2 Estimated Benefits from the Cassava Production Technology Adoption

The estimated benefits accruing to different groups of society from the adoption of improved cassava production technology in the region, under three different scenarios, are reported in Table 6.2.

Under the baseline assumption, the adoption of production technology brought a net gain to society of 14.9 million US$ from 1984 to 1991. From this total gain, fresh cassava urban consumers gain 1.8 millions (12.1%), and cassava producers gain 13.7 millions (91.8%). On the other hand, fresh cassava intermediaries lost 583.6 thousand US$. Dried cassava consumers and processors surplus remained unchanged.

Net benefits to society, under the scenario of 3/4 increase in area planted with cassava due to the adoption of production technology, are 47% higher than the baseline estimate of net benefits. On the other hand, when it is assumed that 1/4 of the increase in area is a consequence of the adoption of production technology, net benefits to the society are 46% lower than the baseline estimates. Therefore a 1% increase in area planted due to cassava production technology, increases total net benefits to society by 0.92%.

Table 6.2.--Change in Accumulative Economic Surplus from the Adoption of Cassava Production Technology for Three Different Scenarios

Scenarios	Economic Surpluses					
	FCS[a]	DCS[b]	MS[c]	PS[d]	CPS[e]	TS[f]
Baseline						
Increase in yield + 1/2 area[g]	1,805.9	0.00	-583.61	0.00	13,706.0	14,926.6
Increase in yield + 3/4 area[h]	2,361.7	0.00	-755.08	0.00	20,347.2	21,951.7
	(30.78)[j]	(0.00)	(29.38)	(0.00)	(48.45)	(47.06)
Increase in yield + 1/4 area[i]	1,222.7	0.00	-400.31	0.00	7,218.8	8,040.1
	(-32.29)	(0.00)	(-31.41)	(0.00)	(-47.33)	(-46.14)

[a] FCS = change in fresh cassava urban consumers surplus (thousand 1991 U.S.$)

[b] DCS = change in dried cassava consumers surplus (thousand 1991 U.S.$)

[c] MS = change in market agents surplus (thousand 1991 U.S.$)

[d] PS = change in dried cassava processors surplus (thousand 1991 U.S.$)

[e] CPS = change in cassava producers surplus (thousand 1991 U.S.$)

[f] TS = change in total economic surplus to society (thousand 1991 U.S.$)

[g] in this scenario it is assumed that all increase in yield and 1/2 of area increase was because of the adoption of improved cassava production technology.

[h] in this scenario it is assumed that all increase in yield and 3/4 of area increase was a consequence of the adoption of improved cassava production technology.

[i] in this scenario it is assumed that all increase in yield and 1/4 of area increase was due to the adoption of improved cassava production technology.

[j] values on parentheses are percentage changes from the baseline assumption that the adoption of improved cassava production is responsible for all yield increase in yield and 1/2 the area increase.

6.1.3.3 Sensitivity Analysis of the Benefits from Technology Adoption

The results of the baseline benefits and the benefits estimated with alternative system parameters for the sensitivity analysis, are reported in Tables 6.1 and 6.3 for the adoption of dry cassava technology and cassava production technology, respectively.

Table 6.3.--Baseline Solution and Sensitivity of System Parameters to Changes in Accumulative Economic Surplus due to the Adoption of Cassava Production Technology.

			FCS	DCS	MS	PS	CPS	TS
baseline estimates			1,805.9[h]	0.00	-583.61	0.00	13,706.0	14,926.6
system parameters	base value	alternat. value						
η_f[a]	-0.64	-0.38	1,869.6	0.00	-673.22	0.00	13,706.0	14,900.8
			(3.53)[i]	(0.00)	(15.35)	(0.00)	(0.00)	(-0.17)
η_d[b]	-3.18	-2.86	1,805.9	0.00	-583.61	0.00	13,707.2	14,927.7
			(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
σ_{fm}[c]	3.00	3.66	1,587.9	0.00	-615.07	0.00	13,706.0	14,677.2
			(-12.07)	(0.00)	(5.39)	(0.00)	(0.00)	(-1.67)
σ_{dp}[d]	0.96	0.86	1,805.9	0.00	-583.61	0.00	13,706.1	14,926.8
			(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
e_m[e]	10.00	100.00	1,550.0	0.00	-63.35	0.00	13,706.0	15,191.0
			(-14.17)	(0.00)	(-89.15)	(0.00)	(0.00)	(1.77)
e_p[f]	1.00	0.50	1,805.9	0.00	-583.61	0.00	13,706.2	14,926.8
			(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
e_c[g]	0.00	1.00	1,803.9	0.00	-583.18	0.00	13,706.0	14,925.2
			(-0.11)	(0.00)	(-0.07)	(0.00)	(0.00)	(-0.01)

[a] η_f = price elasticity of demand for fresh cassava

[b] η_d = price elasticity of demand for dried cassava

[c] σ_{fm} = elasticity of substitution between farm and marketing inputs

[d] σ_{dp} = elasticity of substitution between farm and processing inputs

[e] e_m = price elasticity of supply of marketing inputs

[f] e_p = price elasticity of supply of processing services

[g] e_c = price elasticity of supply of cassava on the farm

[h] The numbers in the matrix are the changes in fresh cassava urban consumer surplus (FCS), dried cassava consumers surplus (DCS), cassava producers surplus (CPS), marketing agents surplus (MS), dried cassava processors surplus (PS), and total surplus to the society (TS) in 1991 thousand dollars.

[i] The numbers in parentheses are percentage changes from the baseline solution when the system parameters change to the alternative value. They are calculated as the new measure of surplus less the base measure as a percentage of the base measure.

6.1.3.3.1 Price Elasticity of Demand for Fresh Cassava (η_f)

The baseline estimates were generated with the price-elasticity of demand for fresh cassava (η_f) estimated for Barranquilla (η_f = -0.64), which is the most important metropolitan area of the region. The alternative measure for the elasticity of demand of fresh cassava is the one estimated for Sincelejo (an intermediate rural town with an absolute higher consumption of fresh cassava than Barranquilla), which is equal to -0.38.

The results reported in Tables 6.1 and 6.3, show that fresh cassava urban consumers with absolute higher levels of consumption gained more than the ones with absolute lower levels of consumption. Market agents and cassava producers, who transport and sell their product in rural intermediate towns, with absolute higher levels of fresh cassava consumption, lost more and gain less, respectively, than the ones who sell their product in urban metropolitan areas, with lower absolute levels of consumption. Net benefits to society were higher when the product was sold in urban metropolitan areas than when it was sold in intermediate rural towns. As could be expected, fresh cassava consumers with higher absolute levels of consumption and a lower elasticity of demand for fresh cassava, will gain more from a technological innovation in the production and/or marketing of cassava. It is important to note that the results from the cross-sectional analysis on fresh cassava consumption showed that poor cassava consumers have a lower elasticity of demand than the rich ones, and therefore, gain more from this type of technological innovation than rich cassava consumers.

6.1.3.3.2 Price Elasticity of Demand for Dried Cassava (η_d)

The baseline estimate of the price-elasticity of demand for dried cassava was not estimated in this study but was taken from a study by Janssen (1986), who estimated the national demand for dried cassava. Using bi-annual data, he calculated an arc-price elasticity of demand for dried cassava of -3.18. In order to analyze the sensitivity of the elasticity of demand for dried cassava, a 10% decrease in this parameter was simulated. The results show that the estimated benefits do not change significantly when this parameter is decreased. Net benefits to society from the adoption of dry cassava technology only decreased by 0.04% while net benefits from the adoption of cassava production technology remained unchanged.

6.1.3.3.3 Elasticity of Substitution between Farm and Marketing Inputs (σ_{fm})

Two similar but different estimates of the elasticity of substitution between farm and marketing inputs were estimated in the section on cassava marketing. The elasticity estimated using the George and King methodology (σ_{fm} = 3.00) was used for generating the baseline benefits. The sensitivity analysis was conducted with the elasticity estimated by using the Wohlgenant methodology (σ_{fm} = 3.66). The results show that when a change is simulated with a slightly higher elasticity of substitution, consumers gain less, market agents loose more, and producers gain more, resulting in an increase in net benefits to society of 1.9% and 11% in the case of dry cassava technology and cassava production technology, respectively.

6.1.3.3.4 Elasticity of Substitution between Farm and Processing Inputs (σ_{dp})

The baseline estimation of the benefits from technology were generated with the elasticity of substitution estimated in the processing section by estimating a cost function (σ_{dp} = 0.96). As part of the sensitivity analysis a 10% change in the elasticity of substitution between farm and processing inputs was also simulated. The results show that the benefits do not change significantly when the elasticity of substitution between farm and processing services decrease by 10% and net benefits to society only decrease by -0.14% in the case of the adoption of dry cassava technology and do not change in the case of the cassava production technology.

6.1.3.3.5 Elasticity of Supply of Marketing Inputs (e_m)

In the case of the elasticity of supply of marketing services (e_m), the sensitivity analysis was conducted by running the model first with an elasticity which is high but not perfectly elastic (e_m = 10), and second with an approximation to an infinite price-elasticity of supply of marketing services (ϵ_m = 100)[5]. As the elasticity of supply of marketing services becomes more elastic, fresh cassava consumers gain less, intermediaries will loose less, and cassava producers will gain more. Therefore, an increase in the fresh cassava market efficiency, that would increase the elasticity of supply of marketing services, would increase the benefits perceived by producers from technological innovation, but would decrease the benefits perceived by fresh cassava consumers. On the other hand, as the marketing system for fresh cassava becomes more efficient, market agents would loose less as a result of technological innovation.

6.1.3.3.6 Elasticity of Supply of Processing Services (ϵ_p)

The baseline estimates were generated by using a unitary elasticity of supply of processing services, which means that an increase in the price of processing services of 1% will increase its supply by 1%. A sensitivity analysis was conducted by assuming that the supply of processing services is relatively inelastic (ϵ_p = 0.50), but the results show that net benefits from the dry cassava technology adoption only decrease by 0.07% and net benefits from the production technology do not change when a lower elasticity of supply of processing services is used and the distribution of the benefits do not change significantly[6].

6.1.3.3.7 Elasticity of Supply of Cassava on the Farm (ϵ_c)

The sensitivity analysis for the elasticity of supply of cassava (ϵ_c) was conducted by using two different estimates reported in the cassava production section (Section 2). For the baseline estimates, the own-price elasticity of supply estimated by the Nerlove supply model (ϵ_c = 0) was used. For the sensitivity analysis, the system was simulated with ϵ_c = 1, which was the result obtained by estimating a cassava production cost

[5] See the section on Cassava Marketing for a more detailed discussion.

[6] See the section on Cassava Processing for a more detail discussion on the elasticity of supply of processing services.

function with time series data from a technological package for a "municipio" of the Department of Sucre.

The results show that an increase in the elasticity of supply of cassava from zero to one decreases benefits to fresh cassava consumers, decreases losses to market agents, increases benefits to producers, and increases total gains to society. Therefore, cassava producers that react more to changes in prices, will gain more from technological innovation than the ones who show less response to price changes. In general, farmers with less production constraints (i.e. land and credit availability), who can more easily react to price changes and adopt new technology will gain more than farmers with more production constraints who will not adopt improved production technology as easily.

6.1.4 Validation of the Estimated Benefits from Technology

The estimated benefits from the adoption of cassava drying and production technology will be validated in three different ways. First, the estimated ex-post benefits will be compared with the ex-ante estimation of benefits made by Janssen (1986). Second, the estimated benefits will be compared with the calculated observed benefits in the region between 1984 and 1991. And third, the incidence of the estimated benefits will be compared with Alston's (1990, p.18) expected incidence of benefits. Table 6.4 shows the ex-post estimated benefits from technology, the ex-ante expected benefits estimated by Janssen (1986), and the calculated ex-post observed benefits.

6.1.4.1 Ex-ante versus Ex-post Estimation of Benefits

In order to measure the expected benefits of the cassava drying technology, Janssen (1986) analyzed the influence of market risk on cassava production and also evaluated the development of fresh cassava versus dried cassava demand. The results show that if there would be no market improvement, production would not change significantly and the cassava industry would stagnate. Fresh cassava consumption was also expected to fall as well as employment in cassava production and marketing.

Table 6.4.--Economic Benefits of the Integrated Cassava Project in the North Coast of Colombia.

Group of the Society	Total ex-post Estimated Benefits from Technology	Total ex-ante Estimated Benefits from Technology[a]	Total Observed Benefits
Fresh Cassava Consumers	2,038.55	-5,700	5,210.9
	(9.32)	(-16.38)	(19.44)
Dried Cassava Consumers	4,334.00	7,200	5,278.5
	(19.82)	(20.69)	(19.70)
Cassava Market Agents	-661.37	-	-7,087.1
	(-3.02)	-	(-26.44)
Dried Cassava Processors	1,149.50	-	3,323.1
	(5.26)	-	(12.40)
Cassava Producers	15,013.00	33,300	23,066.3
	(68.64)	(95.69)	(86.07)
Net Benefits to Society	21,872.10	34,800	26,801.0

[a] The ex-ante estimated benefits from technology were estimated by Janssen (1986).

[b] The values in parentheses are the changes in economic surplus in thousand 1991 U.S.$.

[c] Values on parentheses are the percentage gains for each group of society from the total change in economic surplus.

On the other hand, if the cassava drying technology would be adopted successfully, cassava production was expected to increase by 38.5% in a period of ten years after the introduction of the technology. Average yields were expected to increase by 20% and the area planted with cassava by 15%. A higher production increase was expected for the larger farmers since they have less production constraints. On-farm cassava price, was therefore, expected to decrease by 3.5%, because of the increased cassava production. Benefits to the cassava producers were estimated at 33 million US$.

Seven years after the introduction of the cassava drying technology, there has been an increase in cassava production of 168% in the North coast of Colombia. Average yields and area planted increased by 37% and 116%, respectively. Therefore, the expected increase in cassava production was lower than the observed increase. This difference between expected and observed increase in production could be explained, in part, by the fact that Janssen did not calculated the indirect effect of the introduction of the cassava drying industry as an incentive for the adoption of cassava production technology. The adoption of production technology has had a higher impact on the increase in cassava production than the adoption of the cassava drying industry by itself, as expected by Lynam (1986). He stated that the secondary impact of cassava utilization technology on production response deepens the income generation potential of the technology adoption. There were also other exogenous factors that influenced this increase in production, as discussed in Section 2, that were not taken in account in the expected benefits. Since cassava production increased more than expected, on-farm prices also decreased more than expected. On-farm cassava prices paid by the fresh market and the dried cassava industry decreased by 30.4 and 9.5%, respectively. Even though cassava production increased more than expected, ex-post estimated benefits perceived by cassava producers from technology were only 15 million US$. Ex-post estimated benefits for producer were therefore 55% lower than expected benefits (this difference in estimated benefits could be explained by the fact that producer prices decreased more than expected, because of the higher increase in production).

Demand for cassava was expected to increase, which in turn was supposed to have an upward pressure on fresh cassava prices and decrease consumption. Accordingly, fresh cassava consumers were expected to suffer from the increased price competition, loosing 5.7 million US$. Since the production of cassava increased more than what was expected by Janssen (1986), the supply of fresh cassava increased, decreasing retail cassava prices and therefore increasing consumption. Consequently, fresh cassava consumers gained 2 million US$ instead of loosing from the adoption of technology.

Dried cassava was expected to increase to 80,000 MT by the end of the ten year period. The potential demand for dried cassava in Colombia was estimated at 140,000 MT, which represented a demand of 350,000 MT of cassava roots. Hence, the animal feed industry was expected to receive a benefit of 9 million US$. After ten years of the installation of the first pilot cassava drying plant and seven years of the beginning of the commercial phase of the project only 22,500 MT of dried cassava were produced in 1991 in the North coast of Colombia. Therefore, dried cassava consumers only gain 4.3 million US$ (52% less than the expected benefit).

The total expected benefits to society in the ten year period after the introduction of technology were estimated at 35 million US$. On the other hand, ex-post estimated total benefits to society, after seven years from the beginning of the commercial phase of the project, are 22 million US$ (37% less than expected by the ex-ante analysis).

6.1.4.2 Ex-post Estimated Benefits from Technology versus Total Observed Benefits

Total estimated benefits for society from the adoption of technology and total calculated observed benefits are reported in Table 6.4. It can be noted that estimated total net benefits for society are 22% lower than the total calculated benefits.

Cassava producers gain in total 23 million US$, but only 60% of these benefits were induced by the adoption of technology. The other 40% of the benefits, were in part, induced by the Land Reform Program of the Colombian Government and the improvement of credit availability to small cassava producers.

Fresh cassava consumers total benefits, in the seven-year period, were 23% higher than the benefits produced by the adoption of cassava technology. Therefore, 80% of total benefits perceived by fresh cassava consumers was generated by technology, but the remainder 20% was due to exogenous factors. One exogenous factor that may have influenced fresh cassava consumers benefits was the increase in price of fresh cassava substitutes. Since the results show that fresh cassava consumers respond to changes in the price of cassava substitutes, they increase their consumption of cassava even more, obtaining higher benefits.

Total observed benefits to the animal feed industry (dried cassava consumers), were 22% higher that the estimated benefits from technology. This difference is explained by the fact that it was perceived that technology put an upward pressure on dried cassava prices, increasing dried cassava prices by 0.45% per year. Contrary to this, the animal feed industry fixed the price paid for dried cassava to 0.80 times the domestic price of sorghum. Therefore dried cassava prices decreased by 11.3% from 1990-91, as a response to the declining price of sorghum, when the higher volume of dried cassava was produced. Hence, total observed benefits to the animal feed industry was higher than the estimated benefits from technology.

Even though dried cassava prices did not increase as expected as a response to the cassava drying technology adoption, total observed benefits to dried cassava processors were 189% higher than the benefits brought by the adoption of the technology. This may be caused by the increase in cassava production due to other factors besides cassava technology, which put a downward pressure on the price of cassava roots. This decrease in the cost of the most important input in the cassava drying industry, outgrew the benefits generated by the cassava drying technology itself.

The difference between the estimated loss in market agents surplus and the total observed loss is rather large. If the elasticity of supply of marketing services would be perfectly elastic, market agents surplus would not change as a consequence of the adoption of technology at other levels of the system. By assuming that the elasticity of supply of marketing services was high but not perfectly elastic ($\epsilon_m = 10$), a loss to market agents of 661 thousand US$ versus the observed lose of 7 million US$ was estimated. This may imply that the elasticity of supply of marketing services was even lower ($\epsilon_m = 1$) as a result of the inefficiencies in the fresh cassava market.

6.1.4.3 Incidence of Estimated Benefits versus Alston's Expected Incidence of Benefits

Alston (1990) analyzing the incidence of benefits from technical change on surplus measures for the case of two factors with variable factor proportions (p.18), concluded that: (1) an increase in demand ($\alpha > 0$) will benefit suppliers of both inputs and consumers, and (2) an increase in the supply of one input ($\beta > 0$) will benefit suppliers of this input, will benefit the suppliers of the other input as far as the elasticity of substitution between the two factors of production is lower than the elasticity of demand for the product ($\sigma < \eta$), and will also benefit consumers.

In the case of impact from the cassava drying technology we introduced a supply shifter ($\beta_{cd} > 0$) and a demand shifter ($\alpha_{cd} > 0$), as discussed above. Comparing the estimated benefits with the expected incidence of the results from Alston (1990), it is found that they are consistent with prior expectations. The increase in on-farm cassava supply ($\beta_{cd} = 0.1126$), benefitted cassava producers and fresh and dried cassava consumers. The increase in the demand of cassava by the drying plants ($\alpha_{cd} = 20.19$), benefitted cassava producers and dry cassava processors. Market agents lost from the adoption of the dry cassava technology because the elasticity of demand for fresh cassava, in absolute terms, is smaller than the elasticity of substitution between on-farm cassava and marketing inputs ($|\eta_f| = 0.64 < \sigma_{fm} = 3$).

In the case of the impact from the cassava production technology we introduced an on-farm cassava supply shifter ($\beta_{cp} > 0$), as discussed above. Comparing the estimated benefits with the expected incidence of the results from Alston (1990), it is found that the results are consistent with the prior expectations as in the case of the estimated benefits from the cassava drying technology. The increase in supply of cassava on-farm ($\beta_{cd} = 1$), benefitted cassava producers and fresh cassava urban consumers. On the other hand, market agents lost from the adoption of production cassava technology because the elasticity of demand for fresh cassava, in absolute terms, is smaller than the elasticity of substitution between on-farm cassava and marketing inputs ($|\eta_f| = 0.64 < \sigma_{fm} = 3$).

6.1.4 Conclusions

Cassava producers benefitted most from the Integrated Cassava Projects in the region, gaining 15 million US$. Cassava producers with less production constraints (i.e. land and credit availability), were able to more easily adopt improved production technology, and react faster to price changes; received higher benefits from technological change than cassava farmers with more production constraints. This was rightly hypothesized at the onset of the Integrated Cassava Projects (Lynam, 1986).

The second group that benefitted most from the Integrated Cassava Projects, were the dried cassava consumers, who are mainly animal feed plants and integrated poultry and pig producers. This group of society gained 4.3 million US$ from the introduction of the cassava drying plants in the North coast of Colombia. Even though this group of society was not targeted as one of the main beneficiaries at the onset of the Cassava Integrated Projects, it is important to realize that the size of these benefits are the driving force behind the strong continuing demand for dried cassava. Without this demand for the product, the introduction of the cassava drying technology in the region would not have been feasible.

Even though cassava producers were the principal beneficiaries from technological changes in the North coast of Colombia, urban fresh cassava consumers also benefitted from the adoption of cassava drying and production technology, obtaining a benefit of 2 million US$. Urban poor consumers, who consume higher absolute levels of fresh cassava and show a lower price elasticity of demand for fresh cassava, are the ones who gained most from the adoption of technology in the region.

Although the group with the smallest total gain from the Integrated Cassava Projects in the region were dry cassava processors, which only gain 1.1 million US$, this group was the second most important group benefitting from the adoption of the dry cassava technology together with cassava producers. However, it must be noted that the majority of the small-scale cassava processors are also cassava producers. As such they receive benefits in two ways. Between 1984 and 1991, approximately 55,318 MT of dried cassava were produced. From this total production of dried cassava, it is estimated that 84% was produced by small cassava farmer associations, who had a total net gain from the adoption of dry cassava technology of 924 thousand US$ during these years. The rest of the benefits of dried cassava processors (176 thousand US$) were received by private processors. It is important to note that as the installation of new drying plants becomes more commercial and less capital intensive because of modifications, barriers to entry into the dry cassava industry decreases, and subsequently the elasticity of supply of processing services increases. As such, this increase will tend to increase the benefits perceived by the dried cassava processors and the cassava producers.

Fresh cassava market agents were the only group that lost as a consequence of the Integrated Cassava Projects in the North coast of Colombia. The loss of benefits to this group is mainly an effect of the inefficiency of the market which makes the elasticity of supply of marketing inputs less than perfectly elastic. A perfectly elastic elasticity of supply of marketing services, will produce no changes in the market agents surplus. Any attempt to further improve the marketing of fresh cassava, by making it more efficient approximating perfectly competitive conditions, will decrease the losses to market agents and increase the gains to fresh cassava consumers.

The cassava drying technology in the North coast of Colombia benefitted mostly dry cassava consumers and processors, but even more important, is the indirect effect of creating an incentive to increase the area planted with cassava and to increase yields, through the adoption of improved production technology. The adoption of cassava production technology benefitted mostly cassava producers and fresh cassava urban consumers.

The net benefits to society from technological adoption, which are estimated at 22 million US$ are smaller than the observed total benefits of 27 million US$. The difference of 5 million US$ between the total observed benefits and the benefits from technology, are due to other exogenous factors. Some of those factors, that have shifted the supply of on-farm cassava further, were land reform policy, increased credit availability to small cassava farmers, and the substitution of yam production area with cassava due to the increasing incidence of Antracnosis, a yam disease.

A major conclusion is the fact that these results prove the importance of the research approach integrating production, processing, and marketing aspects. In the absence of the widened cassava market, cassava production technology adoption would have been significantly less. Moreover, principal beneficiaries would have been fresh cassava consumers and not the small producers to which the technology is targeted. Vice versa, with only processing and marketing innovations - in the absence of production technology - absolute total benefits would be significantly less and the principal recipients would have been the animal feed factories and to a lesser extent processors. The integration of the research has been the prime factor to optimize both absolute benefits and their distribution. As such, the research objectives to target benefits to small producers has been full-filled.

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6.1.3.3.1 Price Elasticity of Demand for Fresh Cassava (η_f)

The baseline estimates were generated with the price-elasticity of demand for fresh cassava (η_f) estimated for Barranquilla (η_f = -0.64), which is the most important metropolitan area of the region. The alternative measure for the elasticity of demand of fresh cassava is the one estimated for Sincelejo (an intermediate rural town with an absolute higher consumption of fresh cassava than Barranquilla), which is equal to -0.38.

The results reported in Tables 6.1 and 6.3, show that fresh cassava urban consumers with absolute higher levels of consumption gained more than the ones with absolute lower levels of consumption. Market agents and cassava producers, who transport and sell their product in rural intermediate towns, with absolute higher levels of fresh cassava consumption, lost more and gain less, respectively, than the ones who sell their product in urban metropolitan areas, with lower absolute levels of consumption. Net benefits to society were higher when the product was sold in urban metropolitan areas than when it was sold in intermediate rural towns. As could be expected, fresh cassava consumers with higher absolute levels of consumption and a lower elasticity of demand for fresh cassava, will gain more from a technological innovation in the production and/or marketing of cassava. It is important to note that the results from the cross-sectional analysis on fresh cassava consumption showed that poor cassava consumers have a lower elasticity of demand than the rich ones, and therefore, gain more from this type of technological innovation than rich cassava consumers.

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6.1.3.3.3 Elasticity of Substitution between Farm and Marketing Inputs (σ_{fm})

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6.1.3.3.4 Elasticity of Substitution between Farm and Processing Inputs (σ_{dp})

The baseline estimation of the benefits from technology were generated with the elasticity of substitution estimated in the processing section by estimating a cost function (σ_{dp} = 0.96). As part of the sensitivity analysis a 10% change in the elasticity of substitution between farm and processing inputs was also simulated. The results show that the benefits do not change significantly when the elasticity of substitution between farm and processing services decrease by 10% and net benefits to society only decrease by -0.14% in the case of the adoption of dry cassava technology and do not change in the case of the cassava production technology.

6.1.3.3.5 Elasticity of Supply of Marketing Inputs (ϵ_m)

In the case of the elasticity of supply of marketing services (ϵ_m), the sensitivity analysis was conducted by running the model first with an elasticity which is high but not perfectly elastic (ϵ_m = 10), and second with an approximation to an infinite price-elasticity of supply of marketing services (ε_m = 100)[5]. As the elasticity of supply of marketing services becomes more elastic, fresh cassava consumers gain less, intermediaries will loose less, and cassava producers will gain more. Therefore, an increase in the fresh cassava market efficiency, that would increase the elasticity of supply of marketing services, would increase the benefits perceived by producers from technological innovation, but would decrease the benefits perceived by fresh cassava consumers. On the other hand, as the marketing system for fresh cassava becomes more efficient, market agents would loose less as a result of technological innovation.

6.1.3.3.6 Elasticity of Supply of Processing Services (ε_p)

The baseline estimates were generated by using a unitary elasticity of supply of processing services, which means that an increase in the price of processing services of 1% will increase its supply by 1%. A sensitivity analysis was conducted by assuming that the supply of processing services is relatively inelastic (ε_p = 0.50), but the results show that net benefits from the dry cassava technology adoption only decrease by 0.07% and net benefits from the production technology do not change when a lower elasticity of supply of processing services is used and the distribution of the benefits do not change significantly[6].

6.1.3.3.7 Elasticity of Supply of Cassava on the Farm (ε_c)

The sensitivity analysis for the elasticity of supply of cassava (ε_c) was conducted by using two different estimates reported in the cassava production section (Section 2). For the baseline estimates, the own-price elasticity of supply estimated by the Nerlove supply model (ε_c = 0) was used. For the sensitivity analysis, the system was simulated with ε_c = 1, which was the result obtained by estimating a cassava production cost

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[5] See the section on Cassava Marketing for a more detailed discussion.

[6] See the section on Cassava Processing for a more detail discussion on the elasticity of supply of processing services.

function with time series data from a technological package for a "municipio" of the Department of Sucre.

The results show that an increase in the elasticity of supply of cassava from zero to one decreases benefits to fresh cassava consumers, decreases losses to market agents, increases benefits to producers, and increases total gains to society. Therefore, cassava producers that react more to changes in prices, will gain more from technological innovation than the ones who show less response to price changes. In general, farmers with less production constraints (i.e. land and credit availability), who can more easily react to price changes and adopt new technology will gain more than farmers with more production constraints who will not adopt improved production technology as easily.

6.1.4 Validation of the Estimated Benefits from Technology

The estimated benefits from the adoption of cassava drying and production technology will be validated in three different ways. First, the estimated ex-post benefits will be compared with the ex-ante estimation of benefits made by Janssen (1986). Second, the estimated benefits will be compared with the calculated observed benefits in the region between 1984 and 1991. And third, the incidence of the estimated benefits will be compared with Alston's (1990, p.18) expected incidence of benefits. Table 6.4 shows the ex-post estimated benefits from technology, the ex-ante expected benefits estimated by Janssen (1986), and the calculated ex-post observed benefits.

6.1.4.1 Ex-ante versus Ex-post Estimation of Benefits

In order to measure the expected benefits of the cassava drying technology, Janssen (1986) analyzed the influence of market risk on cassava production and also evaluated the development of fresh cassava versus dried cassava demand. The results show that if there would be no market improvement, production would not change significantly and the cassava industry would stagnate. Fresh cassava consumption was also expected to fall as well as employment in cassava production and marketing.

Table 6.4.--Economic Benefits of the Integrated Cassava Project in the North Coast of Colombia.

Group of the Society	Total ex-post Estimated Benefits from Technology	Total ex-ante Estimated Benefits from Technology[a]	Total Observed Benefits
Fresh Cassava Consumers	2,038.55	-5,700	5,210.9
	(9.32)	(-16.38)	(19.44)
Dried Cassava Consumers	4,334.00	7,200	5,278.5
	(19.82)	(20.69)	(19.70)
Cassava Market Agents	-661.37	-	-7,087.1
	(-3.02)	-	(-26.44)
Dried Cassava Processors	1,149.50	-	3,323.1
	(5.26)	-	(12.40)
Cassava Producers	15,013.00	33,300	23,066.3
	(68.64)	(95.69)	(86.07)
Net Benefits to Society	21,872.10	34,800	26,801.0

[a] The ex-ante estimated benefits from technology were estimated by Janssen (1986).

[b] The values in parentheses are the changes in economic surplus in thousand 1991 U.S.$.

[c] Values on parentheses are the percentage gains for each group of society from the total change in economic surplus.

On the other hand, if the cassava drying technology would be adopted successfully, cassava production was expected to increase by 38.5% in a period of ten years after the introduction of the technology. Average yields were expected to increase by 20% and the area planted with cassava by 15%. A higher production increase was expected for the larger farmers since they have less production constraints. On-farm cassava price, was therefore, expected to decrease by 3.5%, because of the increased cassava production. Benefits to the cassava producers were estimated at 33 million US$.

Seven years after the introduction of the cassava drying technology, there has been an increase in cassava production of 168% in the North coast of Colombia. Average yields and area planted increased by 37% and 116%, respectively. Therefore, the expected increase in cassava production was lower than the observed increase. This difference between expected and observed increase in production could be explained, in part, by the fact that Janssen did not calculated the indirect effect of the introduction of the cassava drying industry as an incentive for the adoption of cassava production technology. The adoption of production technology has had a higher impact on the increase in cassava production than the adoption of the cassava drying industry by itself, as expected by Lynam (1986). He stated that the secondary impact of cassava utilization technology on production response deepens the income generation potential of the technology adoption. There were also other exogenous factors that influenced this increase in production, as discussed in Section 2, that were not taken in account in the expected benefits. Since cassava production increased more than expected, on-farm prices also decreased more than expected. On-farm cassava prices paid by the fresh market and the dried cassava industry decreased by 30.4 and 9.5%, respectively. Even though cassava production increased more than expected, ex-post estimated benefits perceived by cassava producers from technology were only 15 million US$. Ex-post estimated benefits for producer were therefore 55% lower than expected benefits (this difference in estimated benefits could be explained by the fact that producer prices decreased more than expected, because of the higher increase in production).

Demand for cassava was expected to increase, which in turn was supposed to have an upward pressure on fresh cassava prices and decrease consumption. Accordingly, fresh cassava consumers were expected to suffer from the increased price competition, loosing 5.7 million US$. Since the production of cassava increased more than what was expected by Janssen (1986), the supply of fresh cassava increased, decreasing retail cassava prices and therefore increasing consumption. Consequently, fresh cassava consumers gained 2 million US$ instead of loosing from the adoption of technology.

Dried cassava was expected to increase to 80,000 MT by the end of the ten year period. The potential demand for dried cassava in Colombia was estimated at 140,000 MT, which represented a demand of 350,000 MT of cassava roots. Hence, the animal feed industry was expected to receive a benefit of 9 million US$. After ten years of the installation of the first pilot cassava drying plant and seven years of the beginning of the commercial phase of the project only 22,500 MT of dried cassava were produced in 1991 in the North coast of Colombia. Therefore, dried cassava consumers only gain 4.3 million US$ (52% less than the expected benefit).

The total expected benefits to society in the ten year period after the introduction of technology were estimated at 35 million US$. On the other hand, ex-post estimated total benefits to society, after seven years from the beginning of the commercial phase of the project, are 22 million US$ (37% less than expected by the ex-ante analysis).

6.1.4.2 Ex-post Estimated Benefits from Technology versus Total Observed Benefits

Total estimated benefits for society from the adoption of technology and total calculated observed benefits are reported in Table 6.4. It can be noted that estimated total net benefits for society are 22% lower than the total calculated benefits.

Cassava producers gain in total 23 million US$, but only 60% of these benefits were induced by the adoption of technology. The other 40% of the benefits, were in part, induced by the Land Reform Program of the Colombian Government and the improvement of credit availability to small cassava producers.

Fresh cassava consumers total benefits, in the seven-year period, were 23% higher than the benefits produced by the adoption of cassava technology. Therefore, 80% of total benefits perceived by fresh cassava consumers was generated by technology, but the remainder 20% was due to exogenous factors. One exogenous factor that may have influenced fresh cassava consumers benefits was the increase in price of fresh cassava substitutes. Since the results show that fresh cassava consumers respond to changes in the price of cassava substitutes, they increase their consumption of cassava even more, obtaining higher benefits.

Total observed benefits to the animal feed industry (dried cassava consumers), were 22% higher that the estimated benefits from technology. This difference is explained by the fact that it was perceived that technology put an upward pressure on dried cassava prices, increasing dried cassava prices by 0.45% per year. Contrary to this, the animal feed industry fixed the price paid for dried cassava to 0.80 times the domestic price of sorghum. Therefore dried cassava prices decreased by 11.3% from 1990-91, as a response to the declining price of sorghum, when the higher volume of dried cassava was produced. Hence, total observed benefits to the animal feed industry was higher than the estimated benefits from technology.

Even though dried cassava prices did not increase as expected as a response to the cassava drying technology adoption, total observed benefits to dried cassava processors were 189% higher than the benefits brought by the adoption of the technology. This may be caused by the increase in cassava production due to other factors besides cassava technology, which put a downward pressure on the price of cassava roots. This decrease in the cost of the most important input in the cassava drying industry, outgrew the benefits generated by the cassava drying technology itself.

The difference between the estimated loss in market agents surplus and the total observed loss is rather large. If the elasticity of supply of marketing services would be perfectly elastic, market agents surplus would not change as a consequence of the adoption of technology at other levels of the system. By assuming that the elasticity of supply of marketing services was high but not perfectly elastic ($\epsilon_m = 10$), a loss to market agents of 661 thousand US$ versus the observed lose of 7 million US$ was estimated. This may imply that the elasticity of supply of marketing services was even lower ($\epsilon_m = 1$) as a result of the inefficiencies in the fresh cassava market.

6.1.4.3 Incidence of Estimated Benefits versus Alston's Expected Incidence of Benefits

Alston (1990) analyzing the incidence of benefits from technical change on surplus measures for the case of two factors with variable factor proportions (p.18), concluded that: (1) an increase in demand ($\alpha > 0$) will benefit suppliers of both inputs and consumers, and (2) an increase in the supply of one input ($\beta > 0$) will benefit suppliers of this input, will benefit the suppliers of the other input as far as the elasticity of substitution between the two factors of production is lower than the elasticity of demand for the product ($\sigma < \eta$), and will also benefit consumers.

In the case of impact from the cassava drying technology we introduced a supply shifter ($\beta_{cd} > 0$) and a demand shifter ($\alpha_{cd} > 0$), as discussed above. Comparing the estimated benefits with the expected incidence of the results from Alston (1990), it is found that they are consistent with prior expectations. The increase in on-farm cassava supply ($\beta_{cd} = 0.1126$), benefitted cassava producers and fresh and dried cassava consumers. The increase in the demand of cassava by the drying plants ($\alpha_{cd} = 20.19$), benefitted cassava producers and dry cassava processors. Market agents lost from the adoption of the dry cassava technology because the elasticity of demand for fresh cassava, in absolute terms, is smaller than the elasticity of substitution between on-farm cassava and marketing inputs ($|\eta_f| = 0.64 < \sigma_{fm} = 3$).

In the case of the impact from the cassava production technology we introduced an on-farm cassava supply shifter ($\beta_{cp} > 0$), as discussed above. Comparing the estimated benefits with the expected incidence of the results from Alston (1990), it is found that the results are consistent with the prior expectations as in the case of the estimated benefits from the cassava drying technology. The increase in supply of cassava on-farm ($\beta_{cd} = 1$), benefitted cassava producers and fresh cassava urban consumers. On the other hand, market agents lost from the adoption of production cassava technology because the elasticity of demand for fresh cassava, in absolute terms, is smaller than the elasticity of substitution between on-farm cassava and marketing inputs ($|\eta_f| = 0.64 < \sigma_{fm} = 3$).

6.1.4 Conclusions

Cassava producers benefitted most from the Integrated Cassava Projects in the region, gaining 15 million US$. Cassava producers with less production constraints (i.e. land and credit availability), were able to more easily adopt improved production technology, and react faster to price changes; received higher benefits from technological change than cassava farmers with more production constraints. This was rightly hypothesized at the onset of the Integrated Cassava Projects (Lynam, 1986).

The second group that benefitted most from the Integrated Cassava Projects, were the dried cassava consumers, who are mainly animal feed plants and integrated poultry and pig producers. This group of society gained 4.3 million US$ from the introduction of the cassava drying plants in the North coast of Colombia. Even though this group of society was not targeted as one of the main beneficiaries at the onset of the Cassava Integrated Projects, it is important to realize that the size of these benefits are the driving force behind the strong continuing demand for dried cassava. Without this demand for the product, the introduction of the cassava drying technology in the region would not have been feasible.

Even though cassava producers were the principal beneficiaries from technological changes in the North coast of Colombia, urban fresh cassava consumers also benefitted from the adoption of cassava drying and production technology, obtaining a benefit of 2 million US$. Urban poor consumers, who consume higher absolute levels of fresh cassava and show a lower price elasticity of demand for fresh cassava, are the ones who gained most from the adoption of technology in the region.

Although the group with the smallest total gain from the Integrated Cassava Projects in the region were dry cassava processors, which only gain 1.1 million US$, this group was the second most important group benefitting from the adoption of the dry cassava technology together with cassava producers. However, it must be noted that the majority of the small-scale cassava processors are also cassava producers. As such they receive benefits in two ways. Between 1984 and 1991, approximately 55,318 MT of dried cassava were produced. From this total production of dried cassava, it is estimated that 84% was produced by small cassava farmer associations, who had a total net gain from the adoption of dry cassava technology of 924 thousand US$ during these years. The rest of the benefits of dried cassava processors (176 thousand US$) were received by private processors. It is important to note that as the installation of new drying plants becomes more commercial and less capital intensive because of modifications, barriers to entry into the dry cassava industry decreases, and subsequently the elasticity of supply of processing services increases. As such, this increase will tend to increase the benefits perceived by the dried cassava processors and the cassava producers.

Fresh cassava market agents were the only group that lost as a consequence of the Integrated Cassava Projects in the North coast of Colombia. The loss of benefits to this group is mainly an effect of the inefficiency of the market which makes the elasticity of supply of marketing inputs less than perfectly elastic. A perfectly elastic elasticity of supply of marketing services, will produce no changes in the market agents surplus. Any attempt to further improve the marketing of fresh cassava, by making it more efficient approximating perfectly competitive conditions, will decrease the losses to market agents and increase the gains to fresh cassava consumers.

The cassava drying technology in the North coast of Colombia benefitted mostly dry cassava consumers and processors, but even more important, is the indirect effect of creating an incentive to increase the area planted with cassava and to increase yields, through the adoption of improved production technology. The adoption of cassava production technology benefitted mostly cassava producers and fresh cassava urban consumers.

The net benefits to society from technological adoption, which are estimated at 22 million US$ are smaller than the observed total benefits of 27 million US$. The difference of 5 million US$ between the total observed benefits and the benefits from technology, are due to other exogenous factors. Some of those factors, that have shifted the supply of on-farm cassava further, were land reform policy, increased credit availability to small cassava farmers, and the substitution of yam production area with cassava due to the increasing incidence of Antracnosis, a yam disease.

A major conclusion is the fact that these results prove the importance of the research approach integrating production, processing, and marketing aspects. In the absence of the widened cassava market, cassava production technology adoption would have been significantly less. Moreover, principal beneficiaries would have been fresh cassava consumers and not the small producers to which the technology is targeted. Vice versa, with only processing and marketing innovations - in the absence of production technology - absolute total benefits would be significantly less and the principal recipients would have been the animal feed factories and to a lesser extent processors. The integration of the research has been the prime factor to optimize both absolute benefits and their distribution. As such, the research objectives to target benefits to small producers has been full-filled.