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Integrated Assessment of the Impact of Trade Liberalization

A Country Study on the Colombian Rice Sector

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Foreword

A trade liberalization movement to encourage economies with competitive advantages to produce tradable goods characterized the last decade of the 20^{th} Century. Least Developed Countries (LDCs) adopted this neo-liberal model, making it easier to trade goods, reducing tariffs and unifying aids and commercial restrictions in subsidies. The illusion of these new paradigms was mainly to increase the share of LDCs in agricultural trade.

Yet, in the last years of the twentieth century almost all of the LDCs registered an economic recession with high unemployment rates, income concentration, and lower growth rates. According to the World Bank[1], food imports have grown spectacularly in these countries while developed countries have increased their exports of agricultural products and employment in agricultural activities.

The main interest of international institutions in monitoring welfare and development indicators is to evaluate the sustainability of the development model induced by trade liberalization between countries. One way to understand the impact of trade liberalization in the economies of the LDCs is to study agricultural commodities.

This study is an integrated assessment of the impacts of trade liberalization on Colombia's rice sector. Rice was chosen because it is a semi-annual crop, a basic food for low-income populations, and an employment generator in rural zones. Rice sector trends were evaluated over the last 13 years to measure the direct and indirect impacts of trade liberalization. It was found that the sector's performance was linked to international markets despite domestic protections. Exposition of the sector to new trade policies has generated negative social, economic and environmental impacts. As a complement, a mathematical model was calculated to evaluate input and output productivity in the sector.

The conclusion of this study is that, despite reductions in real costs and producer prices, the Colombian rice sector is more vulnerable each year to international markets because of distortions arising from aids and subsidies in major rice-exporting – and thus price-forming – countries.

[1] See Balcázar Alvaro *et al*., 2003.

Acknowledgements

Several institutions and individuals cooperated in the fruitful completion of this Project. FEDEARROZ sponsored and presented the proposal to the United Nations Environment Programme (UNEP) for the evaluation of the impacts of trade liberalization on the Colombian rice sector. Technical staff from the Agriculture, Environment and External Trade Ministries contributed to this document through their criticisms and comments on the first drafts. Finally, the Universidad del Rosario allowed one of its Master in Economics students to finish his thesis with us.

Major acknowledgments must be made to the Technical Committee composed of Jaime Jiménez, Jairo Hómez, Diego Herrera, Edwin García and José Levis under the leadership of Néstor Gutiérrez. They are each responsible for one of the topics in the final document.

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United Nations Environment Programme

The United Nations Environment Programme (UNEP) is the overall coordinating environmental organization of the United Nations system. Its mission is to provide leadership and encourage partnerships in caring for the environment by inspiring, informing and enabling nations and people to improve their quality of life without compromising that of future generations. In accordance with its mandate, UNEP works to observe, monitor and assess the state of the global environment, improve the scientific understanding of how environmental change occurs, and in turn, how such change can be managed by action-oriented national policies and international agreements. UNEP's capacity building work thus centres on helping countries strengthen environmental management in diverse areas that include freshwater and land resource management, the conservation and sustainable use of biodiversity, marine and coastal ecosystem management, and cleaner industrial production and eco-efficiency, among many others.

UNEP, which is headquartered in Nairobi, Kenya, marked its first 30 years of service in 2002. During this time, in partnership with a global array of collaborating organizations, UNEP has achieved major advances in the development of international environmental policy and law, environmental monitoring and assessment, and the understanding of the science of global change. This work also supports the successful development and implementation of the world's major environmental conventions. In parallel, UNEP administers several multilateral environmental agreements (MEAs) including the Vienna Convention's Montreal Protocol on Substances that Deplete the Ozone Layer, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (SBC), the Convention on Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (Rotterdam Convention, PIC) and the Cartagena Protocol on Biosafety to the Convention on Biological Diversity as well as the Stockholm Convention on Persistent Organic Pollutants (POPs).

Division of Technology, Industry and Economics

The mission of the Division of Technology, Industry and Economics (DTIE) is to encourage decision makers in government, local authorities and industry to develop and adopt policies, strategies and practices that are cleaner and safer, make efficient use of natural resources, ensure environmentally sound management of chemicals, and reduce pollution and risks for humans and the environment. In addition, it seeks to enable implementation of conventions and international agreements and encourage the internalisation of environmental costs. UNEP DTIE's strategy in carrying out these objectives is to influence decision-making through partnerships with other international organizations, governmental authorities, business and industry, and non-governmental organizations; facilitate knowledge management through networks; support implementation of conventions; and work closely with UNEP regional offices. The Division, with its Director and Division Office in Paris, consists of one centre and five branches located in Paris, Geneva and Osaka.

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The Economics and Trade Branch (ETB) is one of the five branches of DTIE. Its mission is to enhance the capacities of countries, especially of developing countries and countries with economies in transition, to integrate environmental considerations into development planning and macroeconomic policies, including trade policies. ETB helps countries to develop and use integrated assessment and incentive tools for sustainable development and poverty reduction. The Branch further works to improve the understanding of environmental, social and economic impacts of trade liberalization and the trade impacts of environmental policies, and to strengthen coherence between MEAs and the WTO. Through its finance initiative, ETB helps enhance the role of the financial sector in moving towards sustainability.

In the field of environmental economics, ETB aims to promote the internalisation of environmental costs and enhance the use of economic instruments to contribute to sustainable development and poverty reduction, including in the specific context of MEAs. The UNEP Working Group on Economic Instruments serves as an advisory body to UNEP-ETB's work programme on economics and has been instrumental in the preparation of UNEP publications on economic instruments.

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Executive Summary

During the 1990s, Colombia's rice growing area decreased by 29 per cent, contrary to other short-cycle crops. This was a consequence of the implementation of the new economic development model named "economic openness" that consisted of a reduction in tariffs and protection for a whole range of goods, mainly food products. During this period, food imports increased by about 388 per cent. Surprisingly, imports of rice and maize increased at a high rate even though these crops are extensively produced in Colombia.

This study is an integrated assessment of the impact of trade liberalization and trade related policies on the Colombian rice sector. The process began in April 2001 when UNEP invited participants from several rice producing countries to a meeting in Geneva to discuss potential studies to assess the economic, social and environmental impacts of the World Trade Organization (WTO) Agreement on Agriculture (AoA). Federación Nacional de Arroceros de Colombia (FEDEARROZ) submitted a proposal that was accepted by UNEP and a Memorandum of Understanding was signed between both institutions. The other six countries carrying out similar studies are China, Côte d'Ivoire, Indonesia, Nigeria, Senegal and Viet Nam.

In Colombia, a multidisciplinary team of private, public, and official consultants was enrolled to develop the project. The rice production chain was represented by FEDEARROZ, the producer association; Induarroz and Moliarroz, the industrial associations; Usocoello, the irrigation district of Coello River association; and Sociedad de Agricultores de Colombia (SAC), the Colombian producer society. The Ministries of Agriculture, Environment and External Trade represented the Government sector. Other Governmental institutions that participated in this research were the Departamento Nacional de Planeación, Corpoica and La Bolsa Nacional Agropecuaria. The process was supervised by a Steering Committee comprising the Project Director, FEDEARROZ's CEO and a representative from the Ministry of Agriculture. The project was financed by UNEP and FEDEARROZ, with additional resources from the Cuota de Fomento Arrocero.

A first international meeting was held in Geneva on 19-20 February 2003 involving the seven countries taking part in these studies and other members of the international working group on rice set up by UNEP to guide and implement the projects and provide comments (members of this working group are listed in the Acknowledgements). This meeting helped shape the study and redirect project objectives, especially in relation to the methodology, and the participating countries learned from each other's methods.

The project adopted a multi-disciplinary approach involving stakeholders from throughout the production chain to discuss sectoral problems. The agricultural and environmental Ministries participated in the whole process with two permanent researchers on the Technical Committee. Two stakeholder workshops were held, with the participation of producers and representatives from industry, irrigation districts, universities, NGOs, international institutions, and the Agriculture and Environment Ministries. The first stakeholder workshop was held in Bogotá and involved a brainstorming on the diverse impacts of trade liberalization on every link in the rice production chain. The Technical Committee developed the project, dividing the research topics into environmental concerns, socio-economic issues, production costs and production analysis. The second stakeholders' workshop analysed and qualified the preliminary results from the Technical Committee with the participation of the Minister of Agriculture.

The draft final report was presented at the second international meeting in Geneva on 18-20 November 2003, following which written comments were sent by UNEP to the respective study team leaders for incorporation as far as possible into the studies.

The data used in this study was obtained from the 1989 and 1999 Rice Producers' Censuses[2] to study general aspects of the rice producer sector. The Periodical National Rice Survey (180 rice producers, 1990-2003) information generated by FEDEARROZ was used for the analysis. Price information collected weekly by FEDEARROZ from the principal centres of production, industry and consumption for the period 1980-2003 was also consulted. Furthermore, information on rice producing areas, production and semi-annual yields, and quarterly consumption came from the National Statistics Agency of Colombia (DANE). Policies and information on the environmental impacts of rice cultivation were obtained from related studies at the Agriculture and Environment Ministries.

Social and economic evaluation included *ex ante* and *ex post* analysis using quantitative methods to analyse the impact of subsidies on international prices, with regression analysis to explain the relationship between rice and its substitutes. Co-integration analysis was used to determine the relationship between Colombian and international rice prices, and to test the relationship between domestic rice prices and the international price of wheat, and between the international prices of rice and wheat (in US dollars) to verify any possible substitution relationships. To evaluate the environmental and some of the social and economic impacts, production costs were calculated by system and semester to identify trends in input-use before and after implementation of trade liberalization. Finally, to measure productivity and technical changes, Transcendental Logarithmic Cost Functions and Tornqvist indexes were used to estimate productivity differences between production systems and input levels in order to recommend more environmentally friendly practices and increase sustainability in the rice sector.

The study also examines the evolution of the sector in light of trade policy developments and connections with international trade agreements. Since 1996 the Colombian rice sector has been reactivated as a result of Government incentives such as storage subsidies and protection from the Community of Andean Nations (CAN) and third parties (price bands, administered trade, etc.) to achieve price stability. Nevertheless, an analysis of price trends in real terms of Colombian rice for the period 1991-2001 shows a price decrease of 38 per cent. Production costs followed a similar pattern with a decrease of 28 per cent because of foreign exchange rate trends and the rationalization of inputs. In addition, the new seed variety Fedearroz-50 contributed to an increase in average productivity of more than one ton per hectare, reducing real costs per hectare by 34 per cent.

These price and cost decreases may suggest that Colombian rice is highly competitive. In fact, by 2003 Colombian rice showed greater disparity in relation to international rice prices despite its increased efficiency. The two main reasons for this are that international prices decreased by 50 per cent during the second half of the 1990s, and subsidies, which form the main component of international quotations, increased by 280 per cent. It is thus interesting to observe the behaviour patterns of domestic rice prices versus international quotations in order to prove the strong relationship between both markets despite Colombian protection mechanisms.

The connections between the Colombian and international rice markets show how substitutability between rice and other imported goods such as wheat and maize in the domestic market pulled prices down when the prices of imported goods decreased. This effect does not appear to be true in other countries where rice and wheat are not substitutable.[3] The relationship between subsidies and the international quotations for

[2] Dane –Fedearroz, I y II Censo Nacional Arrocero, Bogota.
[3] Ramirez Tolosa, 2002.

rice and wheat and the impact of total or partial reductions on subsidies in countries of the Organization for Economic Cooperation and Development (OECD) is also considered.

The economic impacts of trade liberalization on the Colombian rice sector are evaluated by measuring the impact of international subsidies on several variables related to rice production in Colombia. A study on costs observed that the only activity that increased in absolute value was the use of agro-chemicals. To understand this aspect, an econometric model based on costs was developed to analyse agro-chemical productivity changes. It was found that, in general, rice productivity decreased during the 1990s, and the increase in the cost of agro-chemicals was due to an increase in the quantities used rather than an increase in their price per hectare. However, it was interesting to note that the introduction of the Fedearroz-50 rice variety resulted in a reduction in the amount of chemicals and fertilizers used. Finally, some substitutions for chemicals were identified, such as labour.

The social and environmental impacts of trade liberalization and trade-related policies are also considered. Rice cultivation in Colombia was found to have had a number of positive social impacts, such as employment generation in the rice sector and other related industries. However, a number of other issues remain to be solved, such as conflicts over water resources and the need for increased civil participation in decision-making.

The study has found a number of negative environmental impacts. Previously, rice crops were rotated with sorghum, soybeans, maize and cotton, but because of the reduced profit levels for alternative crops producers opted to only cultivate rice to maximize income. This resulted in a reduction in the area cultivated with short-cycle crops and promoted the practice of monoculture, which has serious environmental implications in addition to the fact that the increase in rice productivity using various technological alternatives posed new challenges in relation to the fact that monocultivation is characterized by genetic, physiologic and morphologic uniformity. For instance, the loss of nitrogen resulting from an increase in sowing density encouraged the development of production-adverse factors such as weeds, with consequences in terms of increased costs for inputs and environmental degradation.

Agro-industrial rice production requires agro-chemicals such as fertilizers and plaguicides of different natures, characteristics and formulations. The environmental impacts of each physical element affected are identified. The study describes in detail the applications per activity using periodical survey data collected since 1990 and analyses the advances achieved in terms of more environmentally friendly procedures. In this sense, Integrated Pest Management (IPM) is suggested as the most effective alternative to reduce the use of agro-chemicals. Other important measures aimed at a more environmentally friendly production chain have been an agreement for cleaner production and an agreement with the agro-industrial sector to solve the problem of rice husk disposal. The Union of Producers and the Environment Ministry developed an environmental guide for the rice sub-sector that focuses on guaranteeing production sustainability. Other national level agreements are gradually being implemented within the rice production chain, including water use and proposals to ensure appropriate cultivation management.

Preparation of this document had a special significance for the rice growers union because it involved defining from the outset the path that international trade would take as a result of the creation of the Área de Libre Comercio de las Américas (free trade area of the Americas, ALCA), the Andean Trade Promotion and Drug Eradication Act (ATPDEA) and in light of possible agreements with the USA and Mercado Común del Sur (MERCOSUR). This research served to demonstrate the consequences of 10 years of trade liberalization and provided all the analysis tools to anticipate the consolidation of trade agreements over the next years.

Abbreviations and Acronyms

AES	Allen elasticities of substitution
ALCA	Área de Libre Comercio de las Américas (free trade area of the Americas)
AoA	Agreement on Agriculture
CAN	Comunidad Andina de Naciones (Community of Andean Nations
CAR	Corporación Autónoma Nacional
CEGA	Centro de Estudios Ganaderos y Agropecuarios
CEO	Chief Executive Officer
CIF	Cost, insurance and freight
DANE	Departamento Nacional de Estadística (national statistics agency)
FAO	Food and Agriculture Organization of the United Nations
FEDEARROZ	Federación Nacional de Arroceros
GATT	General Agreement on Tariffs and Trade
GDP	Gross domestic product
ICA	Colombian Agricultural Institute
Induarroz	Federación Nacional de Industriales del arroz
IPM	Integrated pest management
LDC	Least developed countries
MEA	Multilateral environmental agreement
MERCOSUR	Mercado Común del Sur (common market between Argentina, Brazil, Paraguay and Uruguay)
MES	Morishima elasticities of substitution
Moliarroz	Molinería del Arroz
OECD	Organization for Economic Co-operation and Development
PSE	Producer Subsidy Equivalent
SAC	Sociedad de Agricultores de Colombia
UNCTAD	United Nations Committee for Trade and Development
UNEP	United Nations Environment Programme
WTO	World Trade Organization

1. Introduction

Economic openness was adopted in Colombia in the early 1990s, as was the case in several LDCs in Asia and South America. The economic openness model consisted mainly of trade liberalization with a reduction in tariffs. The main observed consequences of this process on Colombia's agricultural sector over the last 12 years have seen a decrease in harvested areas (mainly of cereals) and an increase in cereal imports. In 1991, Colombia was importing 816,000 tons of agricultural products; by 2001, imports had reached 3,986,000 tons. The main increases were maize, of which imports escalated from 8,000 to 1,579,000 tons during this period, as well as beans, sorghum, soy, wheat and rice.

1.1 The Colombian rice sector, 1990-2002

Two of the main production systems that prevail in Columbia are irrigated rice and traditional upland rice. The former is based on the availability of water throughout the productive cycle, is highly mechanized, uses modern inputs and has good yields. In some activities, capital and labour are combined. Traditional upland rice depends on rainfall, which varies according to the geographical location. The technological level is the same as irrigated rice, but risk levels are higher because of climatic unpredictability. The main problem with the traditional upland rice system is the concentration of activity at harvest time and for the transportation of the crop, and the need for huge amounts of storage space over a short period of time.

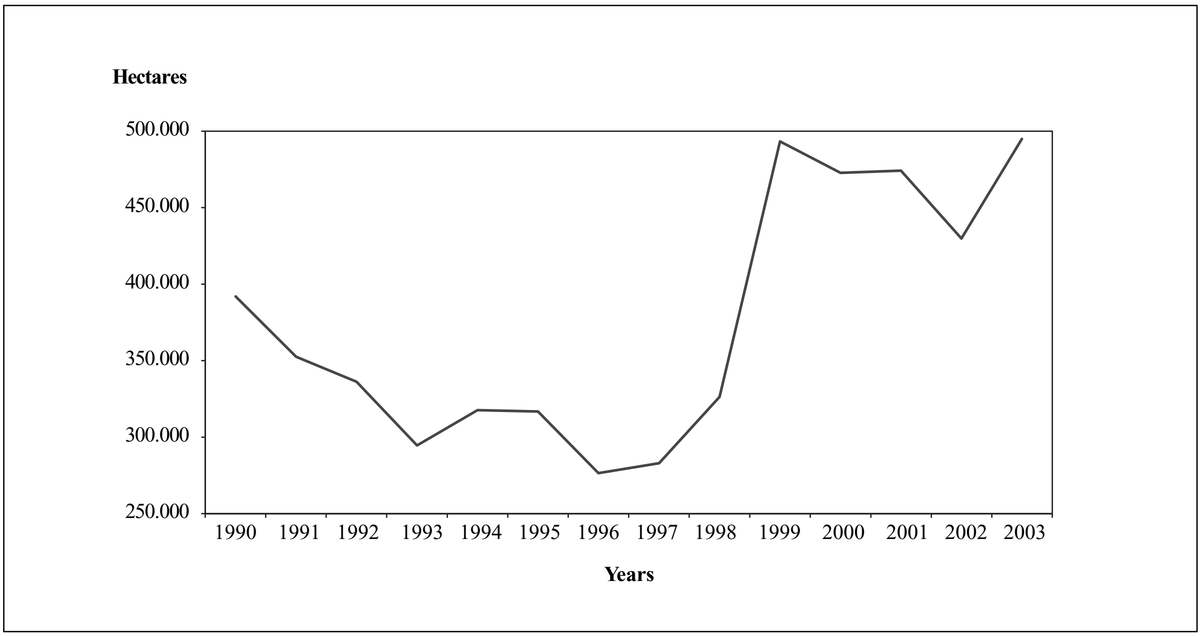
The production system does not determine the size of the productive unit or property. There are production units of all sizes and types in both systems. Sixty seven per cent of mechanized rice production takes place within the irrigated rice production system and 33 per cent in the traditional upland (rain fed) rice production system.

A third production system, manual traditional upland rice, prevails in the jungle zones of northern Colombia and in Chocó. In this system the rice is sown manually on riverbanks, on small properties, and for private consumption. Yields are about one ton per hectare. This production system accounts for 6 per cent of the rice-growing area and 1.5 per cent of the country's total production, but occupies half of Colombia's rice producers. The importance of this system lies in the fact that it provides food security for communities that are isolated from markets. Furthermore, it is environmental friendly since it does not make use of agro-chemical inputs, and it makes use of native varieties, thus preserving these from extinction.

Throughout this study we refer to 'mechanized rice' which includes both irrigated and rain fed mechanized rice production systems together, 'irrigated rice' (which is always mechanized) and 'mechanized rain fed rice' (as opposed to the manual rain fed rice production systems prevalent in the jungle zones).

Rice-related trends during the economic openness period are of particular importance since rice is the staple food of low-income households and provides employment in rural areas. Among the short-cycle crops, maize occupies first place in terms of the area harvested (575,000 Ha), followed by rice (448,000 Ha), and other crops such as cassava, potatoes, beans, sorghum, cotton, *ñame*, wheat, tobacco, sesame, barley and peanuts (less than 200,000 Ha in total). As can be seen from Figure 1.1, in 1990 the area harvested with rice was about 400,000 Ha, followed by a downward trend until

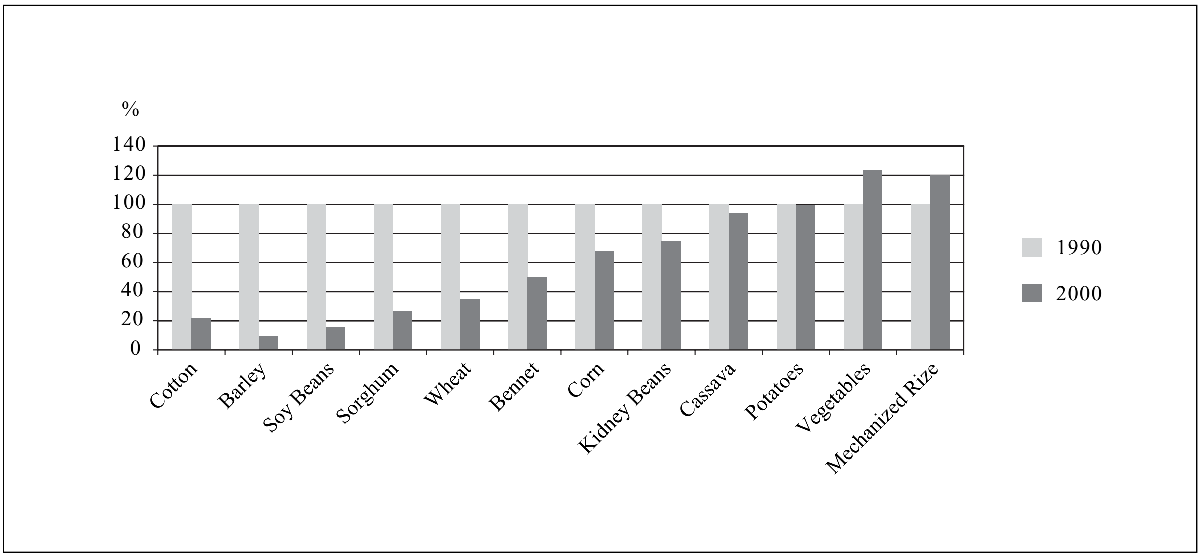
Figure 1.1: Area cultivated with rice in Colombia, 1990-2003



1996 to 270,000 Ha, and then a sharp increase to 490,000 Ha in 1999. The additional land used for rice-cultivation was previously used for growing other short-cycle crops. Over the last 3 years, the area cultivated with rice has fluctuated because of climatic conditions, but is otherwise steady.

As can be seen from Figure 1.2, between 1990 and 2001 the area cultivated with semi-annual crops decreased on average by 29 per cent, while there was a small increase in the areas cultivated with rice and vegetables. The mechanized rice growing area increased by 20 per cent in that period. It can be deduced from this that the increase in the rice-growing area was due to an increase in small-scale farming and a reduction in crop rotation between rice and other substitutive transitory crops.

Figure 1.2: Semi-annual crops (comparison), 1990 vs 2000, 1990=100



Source: SAC, CEGA, FEDEARROZ.

During the last 3 years, rice production has exceeded 2 million tons of dry paddy rice per annual cycle (two harvests), as Table 1.1 shows. Commonly, Colombia has a rice deficit during the first semester of the year, and a surplus during the second, which requires storing rice from the surplus period until the following deficit period. On average, however, Colombia has a 5 per cent deficit overall, which has to be covered with imports of rice and other low-price substitutes such as wheat.

Biological research has played an important role in Colombian rice production. In 1961 paddy rice yields were only about 2 tons per hectare. Between 1966 and 1973 yields increased to 5 tons per hectare. The latter period was marked by the "Green Revolution" lead by the Colombian Agricultural Institute (ICA), the International Centre of Tropical Agriculture (CIAT) and FEDEARROZ. These institutions shared basic management and technological diffusion research until the 1980s. Since then responsibility has been exclusively in the hands of FEDEARROZ.

During the following two and a half decades, technological efforts centred on maintaining those yields, which actually increased by 1 ton since 1997 with a new seed variety, Fedearroz-50. Currently, the average yield for rice is 6.5 tons per hectare of green paddy or 5.2 of dry paddy.

Colombia's technical performance is similar to that of other Latin American countries. Yields for irrigated rice are about 5.2 tons of dry paddy rice per hectare. Only Brazil, Uruguay and Argentina, which produce only one crop per year, surpass this performance. However, one of Colombia's advantages with respect to other Latin American producers is that, as a tropical country, it produces two crops per year with an important number of varieties and a total production of 10.4 tons of dry paddy per hectare per year. This facilitates regional specialization and reduces the risk of massive production of a single variety. By 2002, 16 varieties of excellent culinary quality and acceptation were being produced.

The dynamics of the Colombian rice sector are easy to evaluate since there were two national censuses in 1988 and 1999.[4] In the period between the censuses the number of rice producers increased from 17,517 to 28,128 (60.5 per cent) and the number of rice farms increased from 19,779 to 33,435, (67.3 per cent). However, the Colombian agricultural environment, which consists of good quality land with water, has not changed significantly over the last 30 years because the irrigated areas have not been modified. It is thus easy to conclude that the size of rice production units has decreased to absorb the

Table 1.1: Area, production and yields: mechanized rice (irrigated and rain fed rice), Colombia, 1990 – 2002

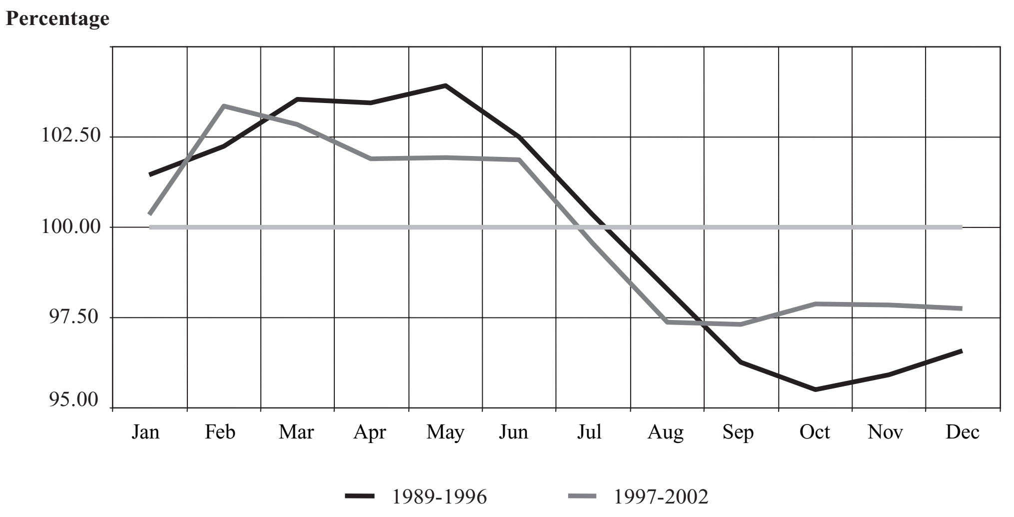
		Hectares	Tons of dry paddy	Tons of dry paddy per Ha
1990		371,965	1,633,455	4.39
1991		332,594	1,475,112	4.44
1992		316,180	1,441,342	4.56
1993		274,545	1,277,387	4.65
1994		297,587	1,400,103	4.70
1995		296,717	1,386,082	4.67
1996		256,450	1,213,583	4.73
1997		262,934	1,177,625	4.48
1998		306,332	1,505,589	4.91
1999		468,031	2,330,085	4.98
2000		447,553	2,204,950	4.93
2001		448,999	2,147,282	4.78
2002	*	407,909	2,016,025	4.94

* Estimated

Source: FEDEARROZ

[4] Dane-Fedearroz, 1990-2000, I y II Censo Nacional Arrocero, Bogotá.

Figure 1.3: Seasonality of producer real prices, Colombia, average 1989-1996, 1997-2002



Note: Indice calculated with the average 'movil' related method.
Source: Arroz en Colombia 1981-2001, FEDEARROZ, 2001.

increase in the number of producers. Most of the rice producers are small-scale, with the majority of Colombian rice producers exploiting farms of less than three hectares. Only 1.7 per cent of the farms are over 100 hectares.

Over the past years, optimal land and infrastructures have acquired a *sui generis* character for warm weather crops such as rice, sorghum and others because of the generation of income from drug traffic. In other words, land has become a form of low-risk investment since its value continues to increase. However, the majority of rice producers (54.1 per cent) rent land instead of owning it, which has a number of consequences that are discussed later in this study.

The Colombian rice sector is backed by a number of important institutions. FEDEARROZ has been representing producers for 60 years. It is financed by a 0.5 per cent tax on product sales. FEDEARROZ researches and disseminates technology, but also unionises producers. Five years ago, the Colombian Agriculture Ministry created the National Rice Council consisting of relative unions and the Ministries of Agriculture, Trade and Economics. Its main function is to link the main rice-related aspects such as import needs, minimum prices and trading conditions for rice. Research, consumption and product trading are also discussed.

1.2 Prices

Colombia has adopted a competition-based price system. There are basically four price levels. The first level is green paddy (25 per cent humidity and 5 per cent impure matters), which is sold by the producers as a raw material. The price depends on grain quality, percentage of humidity, but also on the location of the production zone in relation to industrial zones so price differences for rice of the same quality are based on transportation costs.

The second price level corresponds to wholesale processed white rice, which is traded in bulk quantities of 75 kg for use as a raw material that is then packaged, distributed and sold in packs of less than five kilos (kg). In Colombia there is a market for packed rice in one, 5 and 12.5 kg packs and it is usual to find positioned brands in the market. The quality of this rice is based on the percentage of broken grains.

The highest price level is at the consumer level. The final consumer buys rice in markets and local shops for consumption within one to two weeks. At low-income levels, this rice is purchased in small quantities on a daily basis.

The absolute price at the producer level is about US$ 177 per ton of green paddy or US$ 209 per ton of dry paddy. White rice is priced at about US$ 342 per ton for wholesalers and US$ 464 per ton for consumers. The ratio between the price of wholesale white rice and green paddy is about 2:1, and the ratio between the consumer price and green paddy is about 2.6:1.

The rice market is made up of at least three agents: producers, industrial producers and traders. The number of agents determines competition at each level. At the producer level there are many agents, making it competitive. At the second level there are less agents (currently about 130), and the number has been decreasing over the last 10 years. The lowest number of agents is at the third level, with only two or three agricultural industries and three large supermarkets. The latter is one of the groups that imports rice at prices lower than domestically produced rice.

Prices at the producer and white rice levels are seasonal. During the first semester, the price of the raw material increases, and during the second semester it decreases because of a surplus in August, September and October. Figure 1.3 shows the price variability over the last 12 years. As can be seen, the price of rice was lower in the first semester during the period 1997-2001 due to imports and subsidies to incite rice storage.

Other factors also affect the price trends of Colombian rice besides seasonality. The expectation of imports affects the price level mainly during the harvest season. But the main variables that affect price levels for rice in Colombia are (i) the minimum price level approved by the National Rice Council, (ii) the price of substitute goods (such as potatoes, pasta and bread with a 95 per cent import component), (iii) storage incentives, (iv) administered trade agreements and (v) available income.

In monetary terms, for the 1989-2002 periods, the price of green paddy rice increased from US$ 84,134 per ton to US$ 496,469 per ton. In real terms there is an opposite trend, with a reduction of about 38 per cent during the same period, as shown in Table 1.2. Most of the reduction occurred between 1989 and 1993 when there was a considerable decrease in the growing-area. Since then, however, the real rice price has been fairly stable. This means that rice has been contributing to lowering the Colombian price index.

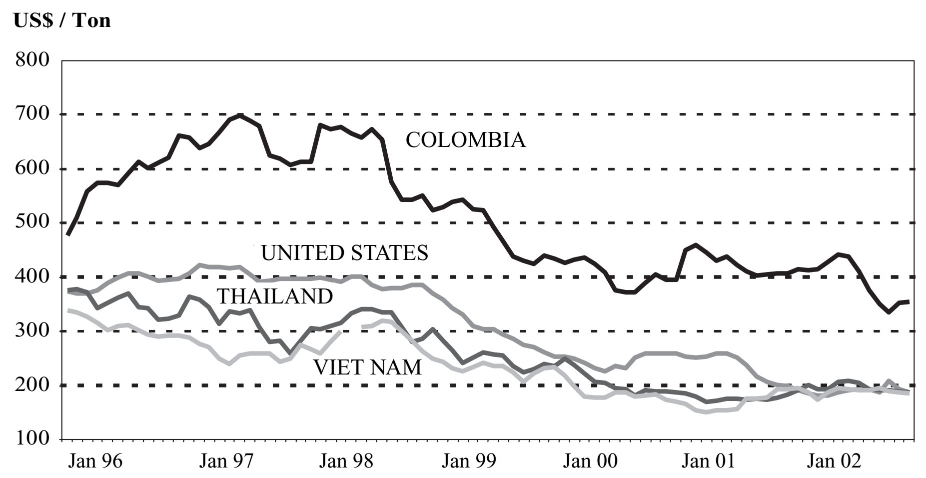
Colombian rice prices in dollars maintain a margin in relation to main export markets around the world. There is no causality relationship as Figure 1.4 shows. This relationship will be explained later in this study.

Table 1.2: Real and current prices for green paddy rice, first semester, 1989-2002

Year	Current $/ton	Real (1978 = 100)/ton	
1989	84,148	9,290	
1990	92,141	7,959	
1991	111,594	7,336	
1992	133,524	6,889	
1993	139,236	5,824	
1994	200,047	6,785	
1995	221,326	6,192	-38%
1996	269,151	6,270	
1997	339,378	6,636	
1998	430,676	7,042	
1999	409,364	5,946	
2000	413,254	5,485	
2001	515,222	6,331	
2002	496,469	5,741	

Source: FEDEARROZ.

Figure 1.4: Real prices in US dollars, white rice, Colombia, USA, Thailand and Vietnam, 1996-2002



Source: FEDEARROZ, Creed Rice Market Report.

1.3 Costs

Production costs depend on the level of technology used, the production system, input prices and production zones. In absolute terms, the production costs for irrigated rice amount to about US$ 1,000 (Pesos 2,947,295) per hectare, as shown in Table 1.3. Around 57.2 per cent of that amount corresponds to land rent, sowing, fertilization, and weed control. In the majority of rice-growing countries, land rent is not considered part of the production costs because it is considered part of the financial benefits from land return.[5] But in Colombia more than half the producers of mechanized rice have to rent their land, and in terms of percentage of total production costs, land rent is the highest, and has to be paid in cash.

Fertilization is the second highest production cost. It requires 300 kg of urea, 50 kg of DAP and 100 kg of KCL per hectare, distributed in four applications over a four-month period. Seeds are the most important production-cost item in the sowing process. Sowing density is about 230 kg per hectare. The cost of controlling weeds has been increasing and currently corresponds to 13.1 per cent of total production costs. On average, three weed control applications are made per crop. Continuous rice growing and bad land management have, together, resulted in an increase in the use of agro-chemicals.

IPM has become a positive common practice in Colombia. IPM involves evaluating the level of infestation and risks before deciding to control pests based on a series of indicators regarding damage levels in relation to the application or non-application of insecticides. As a result, the use of insecticides has decreased and now represents just 2.2 per cent of the total production costs per hectare, compared to 5.5 per cent before.

Land preparation is relatively cheap in Colombia because machinery depreciation was taken into account years ago. Two kinds of rakes are used two or three times per season. Water, fertilization and rent constitute the main cost differences between production systems. Land rent can be up to six times higher in irrigated areas compared to traditional upland (rain fed) rice growing areas.

Costs per hectare increased, in current terms, during the 1989-1994 period despite the depreciation of the Colombian Peso. Because of this depreciation, the real price of rice decreased, via

[5] Garcia, M. and R. Edwin, 2000.

Table 1.3: Estimated national production costs per hectare, percentages, irrigated rice, first semester 2002

	National average (2002) Pesos	Share (%)
1. Technical assistance	26,042	0,9
2. Land rent	476,549	16.2
3. Preparation	150,431	5.1
4. Sowing (including seeds)	363,410	12.3
5. Irrigation	183,410	6.2
6. Fertilization	459,645	15.6
7. Weed control	385,989	13.1
8. Pest control	68,057	2.3
9. Health costs	180,678	6.1
10. Rodents and hand weed killer	34,634	1.2
11. Harvesting	215,105	7.3
12. Transportation	100,639	3.4
Sub-total	**2,644,589**	**89.7**
13. Management	79,338	2.7
14. Interest	177,120	6.0
15. Direct taxes	46,248	1.6
Total cost / Hectare	**2,947,295**	**100.0**
Ton/Ha green paddy		6,16
Cost/ton green paddy		478,612
Ton/Ha dry paddy	5,23	
Cost/ton dry paddy	563,073	

Source: FEDEARROZ.

substitution with imported foods. The producers tried to adjust to these changes in income with decreases in real costs, resulting in a 34 per cent decrease over the period 1989-2001 (see Table 1.4). The bulk of the fall in production costs occurred during the period 1989-1993 as a result of the peso revaluation. The theory anticipates serious decreases in the price of imported inputs as a result of a depreciation process. However, rice growers may not perceive these benefits, partially because of the monopoly structure of the commercialisation of agro-chemicals in Colombia. The same phenomenon occurs when cheap rice imports reach the national market since consumers do not benefit from lower prices. On the other hand, the decreases in real prices and production costs should have benefited the sector's competitiveness on international markets; however it was not sufficient to reduce the gap in view of the drastic decrease in international prices during the same period.

Table 1.4: Production costs per ton, current and real prices, Colombia, first semester, 1989-2002

Year	Current Pesos/ton	Real (1978 = 100)	
1989	89,990	9,396	
1990	107,543	8,713	
1991	135,697	8,387	
1992	147,564	7,148	
1993	168,892	6,729	
1994	199,316	6,454	
1995	247,012	6,597	-34% (1989–2001)
1996	288,079	6,387	
1997	361,531	6,777	
1998	415,524	6,500	
1999	445,407	6,358	
2000	473,603	6,173	
2001	514,710	6,213	
2002	563,073	6,511	

Source: FEDEARROZ.

2. Trade liberalization and trade-related agreements

2.1 International trade

The Colombian economic openness model involved a reduction in tariffs in exchange for a reduction of production subsidies in developed countries. This resulted in an increase in food imports of about 388 per cent and the area sown with semi-annual crops decreased by about 25.9 per cent during the period 1991-2000. From 1991 Colombia became a net importer of rice. On average, Colombia imported 236,000 tons of dry paddy rice per year during the 1990s to cover the deficit caused by an excess of demand over domestic production (see Table 2.1).

The highest import level was in 1998 with 499,000 tons. Suppliers of imported grain have changed through time depending on the supply conditions imposed by the National Rice Council which considered that imports of dry paddy rice benefited industry and compensated them for the absorption of the national crop.

Most imports originated from the USA. The latter increased its exports of dry paddy rice because most Latin American countries followed the Colombian example of importing paddy instead of white rice. Trade with the USA is important because of prices, payment facilities and greater industrial productivity with American paddy rice. Ecuador and Venezuela exported small amounts of paddy rice to Colombia because Ecuador increased its rice-growing areas and the Venezuelan currency

Table 2.1: Rice imports, Colombia, 1990-2002

		Imports dry paddy (tons)	Origin
1990		(39,457)	
1991		(119,255)	
1992		116,553	
1993		52,702	
1994		356,892	
1995		170,876	
1996		284,668	
1997		252,100	
1998	*a)*	449,200	USA 69%; Venezuela 16%; Ecuador 15%
1999	*b)*	270,000	Ecuador 98%
2000	*c)*	178,644	Venezuela 71%, Ecuador 21%, USA 2%
2001	*d)*	321,847	Ecuador 48%, Venezuela 20%, USA 27%
2002	*e)*	127,662	Ecuador 98%

a) 330,000 tons imported from various countries in registered trade + 119,200 tons imported illegally from Venezuela and Ecuador.
b) 76.500 tons imported from Ecuador in registered trade + 193,500 tons imported illegally.
c) 70,000 tons of white rice + 5,000 tons of dry paddy per month imported illegally.
d) 147,445 tons imported from Ecuador in registered trade, 112,402 tons imported from other countries (Induarroz), Comité Nacional de Estadísticas, + 62,000 tons imported illegally.
e) 123,262 tons from administered trade + 4,400 imported illegally.

Source: FEDEARROZ.

(Bolívar) depreciated compared to the Colombian peso. Colombia became the main rice importer of these two countries which exported rice to Colombia at a zero tariff from 1999 in light of the Andean Trade Agreements. However, imports from Ecuador remain restricted in terms of volume and are only over short periods of time because of the low quality and low transportation availability. In Colombia, local industries mix this rice with domestically produced rice and sell it as a national product.

Since January 1998 the USA and Thailand have reduced their prices by more than 50 per cent, which has influenced overall international prices. This has signified a loss in price competitiveness for Colombian rice and caused a drop in the price of domestically produced rice as well. Over the last 3 years, production costs and product prices have decreased by about 30 per cent.

2.2 Trade policy developments

Because of the importance of rice production in Colombia, it has been a key topic in trade negotiations and trade policy developments.

Until the late 1980s, Colombia developed and used an import substitution policy that was radically modified in the early 1990s with the economic openness model, which involved deep economic reform, elimination of price controls, abolition of sustenance policies for production costs, re-establishing imports without quantitative restrictions or Government monopolies, and adopting rates and market prices without subsidies.

Subsequently, a number of relevant changes were made in the agricultural sector, mainly in terms of the composition of internal production and a significant growth in imports. Simultaneously, unfavourable climatic conditions resulted in a fall in international prices and the appreciation of the Colombian peso caused a reduction in the contribution of agriculture to the country's gross domestic product (GDP). An important group of Colombian agricultural products were affected by those economic measures: Colombian imports increased significantly while cultivated areas decreased by almost 400,000 hectares, i.e. 10 per cent of the total cultivated area. Most of the land that ceased to be cultivated was converted to pastures.

After 4 years of similar results – and since the beginning of 1994 – agricultural revitalisation thus became one of the main policy objectives for productive and social reasons as well as for political stability. From a commercial perspective, this has meant that a restricted number of products, including rice, were affected by protection mechanisms such as tariffs, stabilization systems, import administration and safeguards.

2.3 Colombia and the multilateral trade agreements

Colombia participated in the General Agreement on Tariffs and Trade (GATT) talks from the very beginning and, following a period of provisional membership from 1975, it became a full member in 1981 after having negotiated 36 tariff positions, several of which are still effective.

During the WTO Uruguay Round, Colombia acquired tariff commitments from all of its tariff sub-parties as well as commitments on payment reductions for policies identified as export subsidies. It also committed to reductions in aid measures within the Amber Box.

Because of Colombia's status as a developing country, the implementation period and Colombia's commitments in terms of reductions in grants and subsidies were established in agreement with the Special and Differentiated Treatment for Developing Countries. This allows Colombia a ten-year implementation period from 1995 until the end of 2004.

The Global Aid Measure, which includes support of a general character and for particular products, allows a 13 per cent decrease of the consolidated amount over a ten-year period. For rice, the consolidated value included:

- sustenance prices, which were valued at the average of US$ 55.7 million (1986-1988).
- a production credit subsidy of approximately US$ 23.5 million.

- other payments for specific products valued at US$ 11.3 million.

The total Global Aid Measure for rice was thus valued at US$ 90.5 million. In summary, overall help under the Global Aid Measure for the period 1986-88 represented US$ 397.7 million, of which 22.7 per cent was for rice, reflecting the importance of this product in Colombia's agricultural economy. In these circumstances, the *de minimis* internal grant for which Colombia could apply – and which would not be tied to reductions – would amount to US$ 39.7 million.

The export subsidies, which refer to the payments to exporters including those payments mentioned in Article 9 of the WTO AoA, make reference to direct payments, non-commercial inventory sales with prices inferior to domestic ones, production taxes to subsidize exports and internal cost reduction measures, discriminating against the markets and subsidies incorporated in the raw materials. Colombia's reduction commitment, as a developing country, is about 14 per cent in volume and about 24 per cent of the payment budget within a ten-year period. The payment level for rice for the base period was about US$ 118.3 million for 18,911 tons of production. For the year 2002, if the chronogram had been fulfilled, the payment value would have been US$ 96.2 million for a volume of 16,852 tons. However, Colombia revised and corrected its notification after finding that what it previously considered as export subsidies actually corresponds to an indirect tax refund. Additionally, Colombia does not export rice and, moreover, only imports goods according to its need to fulfil domestic demand.

In terms of market access, the AoA sought to make access conditions more transparent, predictable and competitive. The tariff reduction that Colombia committed to was about 24 per cent on average, with a minimum of 10 per cent for each tariff group within a ten-year implementation period. So the basic tariff type for rice was 210 per cent and the consolidated rights type was 189 per cent. These levels correspond to the results of the estimated tariffs equivalent to the base period and defined for the negotiation.

On the other hand, the initial minimum rice stock established to access the market was about 39,598 tons with an applicable tariff of 80 per cent and a final stock of 75,188 tons with the same tariff. This minimum stock, as we will see later, was successfully completed and, moreover, in some periods it was actually exceeded and the applied tariff was inferior.

A special safeguard contingent for agricultural products was included in the AoA and allows additional tariff imposition in the case of an unexpected increase in imports or in the event that an import price should decrease. This safeguard has not been used by Colombia on any product, despite the fact that the tariffs for rice and 56 other products increased to four digits and the application of this measure could have helped. Currently there are 271 products (including rice, cotton, meat, poultry and milk) that could benefit from the Colombian special safeguard contingent.

2.3.1 The absorption agreements and the investment measures agreement related to trade

Another element of Colombia's agricultural policy related to market access is crop absorption. Before being authorized to import commodities, importers are required to demonstrate that they have first purchased domestic production. This policy was notified to the WTO within the framework of the dispositions of the Agreement on Measures of Investment related to trade.

In conformity with Article 5 of the aforementioned Agreement, developing countries were entitled to apply this measure for 5 years after the WTO Agreement came into effect, i.e. until 1 January 2000. However, Article 5.3 allows the possibility of prolonging the transition period depending on the financial, economic and development needs of the country that requests it. Colombia requested such an extension for a further 7 years from the Commodities Trade Council in order to pursue its absorption policy. Nine other countries did the same, but Colombia was the only one that qualified. The Colombian application was supplemented with a request for an exemption under Article 9 of the WTO Agreement for the implementation of an absorption policy for beans, which was applied in 2001. Finally, Colombia's request related to crop absorption was accepted with some modifications, i.e. for a maximum of 4 years and on the basis of a dismount programme that involved a gradual reduction of the crops included in its crop absorption policy. The dismount programme took into account Colombia's sensitive products, with the most sensitive ones (rice, wheat, corn, soy beans, beans and poultry) being the last to be dismounted under the absorption policy. Colombia also committed not to apply the crop absorption policy to any product other than those already included in the dismount programme (see Table 2.2).

On the basis of obligatory crop absorption prior to obtaining access to import products under the TRIMS Agreement, and as a verification mechanism, Colombia has implemented an approval mechanism or non-automatic licenses for the weak agricultural products group, applying an agriculture-production chain concept. This mechanism is mainly applied for cereals and oil seeds and requires importers to first purchase local production according to conditions that satisfy both producers and industrials through the Government guarantee.

In the case of rice, a seasonal contingent is defined in concert with the National Rice Council, which is attended by farmers, industrials, merchants and Government representatives. The Government issues a regulation in which dates and promises for the purchase of the future production are established.

2.3.2 The WTO AoA and the coexistence of sub-regional agreements

The WTO AoA allows for economic integration agreements among nations that apply preferential conditions between each other. The CAN has still not been completely accepted as a customs union, although a high proportion of trade between its member countries is liberated.

The CAN came into effect on 26 May 1969 when a group of South American countries in the Andean area, including Chile, subscribed to the Cartagena Agreement (Andean Pact) with the purpose of establishing a customs union for 10 years. The Andean integration process crossed different stages over three decades. From a basically closed conception of internally focussed integration, in accordance with the import substitution pattern, it was reorientation towards an open regional model.

Currently the CAN is a sub-regional organization. Its members countries are Bolivia, Colombia, Ecuador, Peru and Venezuela and its main objectives are to (i) promote balanced and harmonious development of its member countries under equitable conditions, (ii) accelerate growth through integration and economic and social cooperation, (iii) impel the participation in the

Table 2.2: WTO-agreed dismount programme for agricultural products protected under Colombia's absorption policy

Dismount at 31 December 2001 (19 sub-parties)	Dismount at 31 December 2002 (13 sub-parties)	Dismount at 31 December 2003 (40 sub-parties)
– Ducks and geese – Suets and fats – Dog and cat food – Stearic acid – Oleic acid	– Oil of soya – Palm oil – Fat and oils – Sunflower oil – Cotton oil – Oil of coconut – Oil of turnip – Corn oil – Oil of benne – Oleaginous seeds	– Roosters and hens – Turkeys – Beans – Wheat – Barley – Corn – Rice – Sorghum – Wheat flour and corn – Malt – Gluten of wheat – Starch – Preparations for animals

Source: Ministry of Agriculture.

Table 2.3: Access commitments to the Andean community markets of WTO members (for rice)

Bolivia	Colombia	Ecuador	Peru	Venezuela	
Safeguard	No	Yes	No	No	Yes
Tariff in 2004 (%)	40	189	67.5	68	122
Current access	0	13.681	0	0	30.197
Minimum access	0	75.118	0	0	30.197

Source: Ministry of Agriculture and Secretary of the Andean Community.

regional integration process and achieve gradual formation of a Latin American common market, and (iv) maintain and improve the living conditions of its population.

Trade among Andean Community Countries is liberated in the majority of the sub-parties, with the exception of those contemplated in the Decision 414 that regulates the progressive linking of Peru to the Custom Union. Peru has the dispensation of incorporating its products progressively into the integration process by 2004.

2.3.3 The Andean system of price stabilization

As already mentioned, Colombia has, since the end of the 1980s, switched to a unilateral economic opening process, which implied a radical change in its handling of international trade. For some sectors of the economy, and especially the agricultural sector, the special circumstances of the world market conditioned the use of cost stabilization mechanisms for imports, which translated into the application of a fluctuating tariff depending on international market prices. Thus, when there was an important drop in international prices relative to the historical average of those prices, the basic *ad valorem* tariff, which was relatively low, was increased by a variable component but with a maximum limit representing the consolidated tariff defined by the WTO. Conversely, in the event international prices increased to above the historical average, the tariff would be reduced to zero.

The application of this mechanism made it possible to mitigate the effects of provisional and unexpected fluctuations in international prices that affect the domestic market, making it unstable, affecting revenues or producers' decisions about the time of cultivation, and in some cases harming consumers by forcing them to acquire expensive products on the international market.

From 1991, Colombia used a system of price bands for the import of commodities and then from 1994, with the implementation of the External Tariff and the change from a free trade zone to a custom union of Andean countries, the latter adopted a combined system of price bands that was already being applied by Colombia, Venezuela and Ecuador but with the derivative differences originating from the separate negotiations that these countries made within the WTO. Access commitments to the Andean community rice markets consisted of safeguards, tariffs and minimum access (see Table 2.3).

2.3.4 Objectives of the Andean price bands

The main objective of the Andean agricultural price band system is to stabilize the import costs of a special group of agricultural products characterized by price instability or distortions in the international markets. Member countries apply additional rights to the Common External Tariff when the reference price for those products falls below a certain level. In the same way, member countries apply discounts to the Common External Tariff to reduce import costs when prices rise above a determined level.

This system covers a group of products that are considered sensitive for the internal production of Andean countries, such as rice, palm oil, soy oil, soy, sugar, poultry, wheat, pork, milk and maize.

2.3.5 Consolidated tariffs and applied tariffs for the countries of the Andean Community

Tariffs consolidated by the Andean Community countries differ because of previous commitments or because of internal policies, such as in the case of Peru that consolidated most of its agricultural products at 30 per cent. This can partly be explained by the composition of the agricultural production of Andean countries and its relative overall importance in the economy.

Thus, while Colombia, Ecuador and Bolivia are net exporters of agricultural products to different extents, Peru and Venezuela are net importers of food.

2.3.6 Custom tariffs applied by the CAN

The resulting custom tariff of the system of price bands has varied from 33 per cent in 1995 when the application of the Andean System of Price Bands was first implemented, to 83 per cent in 2001 (see Table 2.4). As will be discussed later, the custom tariff of the price bands is related to international prices and the latter are closely linked to subsidies in the main producing countries.

2.3.7 The Andean safeguards

The Andean Community normative, which allows the non-discriminatory application of safeguards, regulates sub-regional trade. By means of this mechanism countries can limit their imports to those necessary to cover transitory supply shortages and level their internal market prices. They can also apply the safeguards when interferences occur in the internal market because of the lower prices of imports.

2.3.8 Application of regulatory measures

The Superior Council for Foreign Trade has maintained the non-automatic granting of licenses and contingents for rice imports originating from the Andean Community.

On 4 February 2002, the recent safeguard for rice imports from the Andean Community was imposed for a contingent 123,000 tons of dry paddy rice, valid until 30 November 2002, and legal steps are being taken since then for the extension of this safeguard for one more year and for a contingent 150,000 tons of paddy rice.

Colombia's ability to meet its requirement of granting non-automatic licenses for foreign trade and linking imports to the purchase of domestic production, as well as the application of the system of price bands for imports from countries outside the CAN, has strengthened the competitiveness of rice produced within the Andean Community, the members of which benefit from preferential tariffs for goods traded among each other. Thus Ecuador became Colombia's main supply source, except during the years when production in the Andean Community was insufficient to meet demand, mainly because of the adverse climatic conditions resulting from the 'El Niño' phenomenon, and supplies had to be imported from other countries.

Table 2.4: Tariffs - Total for the Andean system of price stabilization for rice, 1991-2001.

Year	Annual average (%)	Minimum (%)	Maximum (%)
1991	41	35	50
1992	22	20	30
1993	37	24	55
1994	34	16	56
1995	33	18	53
1996	16	9	20
1997	21	10	34
1998	21	20	28
1999	46	22	66
2000	70	51	90
2001	83	78	87

Source: Ministry of Agriculture and Secretary of the Andean Community.

2.4 The new agricultural negotiation rounds and other Colombian commercial agreements

The latest round of negotiations on agriculture started at the beginning of 2000, in concordance with Article 20 of the WTO AoA. By November 2001, before the Ministerial Conference of Doha, 121 governments presented a great number of negotiation proposals.

2.4.1 CAN - MERCOSUR negotiations

The expectation from this negotiation in relation to rice was important in view of the presence of large producers from the south cone that showed competitive levels and macroeconomic situations that suggested the possibility of later devaluations. Also, Uruguay and Paraguay's application to receive special and differentiated treatment in terms of access to Andean Community markets for their agricultural products was on the agenda. Negotiations were expected to conclude by the end of 2003, but they have taken a long time, so the validity of the current preferential terms was prolonged and the negations were deferred to the following year. These negotiations have not defined the treatment of sensitive products such as rice.

2.4.2 Free Trade Area of the Americas (ALCA)

Custom exemptions for the ALCA are programmed for 15 February 2003, and improvement applications are expected for the middle of 2003.

Rice is one of the most important crops for the countries of the Americas, including the USA. Access negotiations related to rice will probably be framed at the same time as a customs exemption chronology conditioned by the reduction in export subsidies and domestic aid as defined by some developing countries.

2.5 Conclusion

Colombia's unilateral economic opening from the end of the 1980s has also signified a trade opening in the Colombian rice sector. This has resulted in Colombia becoming a net importer of rice since 1992. However, Colombia has not noted an increased dependence on rice imports for domestic consumption since the implementation of the WTO AoA in 1995. On average, 5 per cent of total domestic consumption is covered by imports. Colombia has applied the mechanisms foreseen in the AoA, except for the Agricultural Special Safeguard for the handling of its external trade. The applied tariff has been traditionally lower than the one consolidated through the WTO, mainly because a high percentage of Colombia's imports originate from the CAN and are thus exempt from tariffs.

Currently, high subsidies for rice on the international market means that the price of rice is the one most affected by export subsidies and domestic aid, which in turn means lower prices and high tariff bands. Consequently, the competitiveness of rice produced in Andean countries, especially Colombia, has strengthened because of its lack of budget to support exports.

The most recent negotiations of the AoA must once again face the interests of the USA since the latter has reinforced its domestic aid mechanisms despite proclaiming market liberation, as well as the interest of the European Union which wishes to reduce its aid mechanisms without losing self-sufficiency given the significance of high costs of agricultural issues for common policies, especially now that new, less-developed countries are integrating the international markets.

The new AFTA negotiations with MERCOSUR members are still in the definition stages in terms of how to deal with sensitive products and custom exemption lists. There are, as yet, no indications as to how rice will be dealt with, although from an internal agricultural policy point of view it will receive special treatment.

3. Integrated assessment results

Based on an extensive production analysis, the details of which are presented in the annex of this study, it is clear that mechanized rain fed and irrigated rice production systems are different. Water, which is the main difference between the production systems, may play an important role in determining not only technical biases but also input and total product productivity.

In the case of mechanized rain fed rice production, the empirical estimation of a Translog cost function and input shares for the Fedearroz-50 rice variety showed that:

- Production is capital and labour saving, meaning that their use is decreasing through time in favour of the use for agro-chemicals that are used intensively.
- Introduction of Fedearroz-50 only affected fertilizer use in a negative way, meaning that fertilizer-use decreased with the introduction of this variety.
- Labour appears to offer an opportunity to reduce the use of agro-chemicals as it is a substitute for fertilizers and chemicals. Labour is the only factor for which productivity increased through the analysis period. IPM may act as an incentive to encourage producers to reduce costs via this substitution.

In the case of irrigated rice, estimations showed that:

- Production is chemical-intensive but allows savings in other factors, meaning that, over time, agro-chemical use has been increasing while the use of other factors has been decreasing.
- The introduction of Fedearroz-50 increased capital use and reduced fertilizer and chemical use. The objective of this variety was accomplished in terms of environmental benefits reducing the use of agro-chemicals.
- Again, labour appears to offer an opportunity to reduce the use of agro-chemicals since the latter can be substituted by labour and appear to be unproductive. Suggestions are the same as those for mechanized rain fed rice.

A comparison among production systems shows that irrigated rice is much more productive than mechanized rain fed rice. A partial explanation may be the availability of water for irrigated rice that makes it independent from the unpredictability of rainfall, which in turn may explain why inputs are more productive in irrigated rice despite similar factor availability among production zones. It is also clear that the use of agro-chemicals as a set is intensive in both production systems, showing that some policies, such as permits to use generic products and a lack of control, expose rice production to potential negative environmental externalities.

Policies to increase the use of labour as a substitute for fertilizers and chemicals may provide an opportunity to reduce the risk of environmental damage and to reactivate the economy throughout Colombian rice production zones.

It is also clear that the Colombian Ministry of Environment and FEDEARROZ need to play a more active role in inducing rice producers to adopt cleaner practices. The implementation of IPM may be an alternative that produces results consistent with the objective of increasing the level of labour used for rice production in substitution to agro-chemicals.

Actions by the Government and private entities could be focused on providing producer and technical assistance to create a culture around the use of IPM.

3.1 Economic impacts

The perception of Colombian rice producers with regard to the social and economic impacts of trade liberalization originates partially from the protection that grain exporters give to producers and the commercial sector. Many consider rice as a strategic product for food security as well as a source of foreign exchange from exports. Historically, rice-producing countries have intervened in the production, processing and commercialisation of rice through several policies to sustain prices, income, tariffs, rates or export subsidies. As different reports have shown,[6] domestic aids to producers, export subsidies and other support measures have affected the price of rice on international markets, mainly in terms of a downward trend and price volatility. Some studies show that subsidies and commercial barriers contribute to price volatility and have adverse effects on rice production levels in other countries. Furthermore, subsidies cause the international price of rice to drop, and this has a negative impact on countries such as Colombia that provide more limited government support for rice production and commercialisation. Thus, in countries where producers benefit from government support the cultivated area remains artificially high, whilst in other countries where producers receive less support the cultivated area is decreasing. This section attempts to measure the impacts of international subsidies on some aspects of rice production in Colombia.

This section also examines the links between domestic rice prices and those on international markets. It seems that Colombia is a price taker, meaning its transactions do not have an effect on the international market. On the other hand the Government tries to compensate national production with protection measures in light of international price distortions. Indeed, cost reductions and decreases of approximately 35 per cent in domestic rice prices during the last 12 years indicate that national producers are exposed to the effects of international markets despite the direct tariff protections and other indirect protections, and the income that should have been generated through these protections has not materialised because of the linkages between domestic and international rice prices.

The five main topics in this section are as follows:

1. a description of the international rice market, traded volumes and main actors;
2. an analysis of the OECD[7] subsidies to producers, showing which countries subsidize grain, the magnitude of these subsidies and their particular characteristics;
3. an econometric exercise to measure the effect of subsidies on international grain prices, and an evaluation of the impact of the elimination of subsidies on prices;
4. an analysis of the mechanisms that link the domestic and international rice markets;
5. measurement of the impact of OECD subsidies on Colombian rice sector variables.

3.1.1 Main production agents and global rice trade

To measure the impact of subsidies on trends in rice prices, it is necessary to analyse production and international trade behaviour. The data presented hereafter are based on information from the Food and Agriculture Organization (FAO) Data Base (1961-2000). In 2001, production of white rice reached 338.8 million tons, but only 6 per cent of this was traded on international markets, which suggests that rice is mainly produced to meet domestic needs and any surplus is then traded on international markets.

World rice production is highly concentrated; 90 per cent of rice is produced by just 12 countries: China, India, Indonesia, Bangladesh, Viet Nam, Thailand, Myanmar, Philippines, Japan, Brazil, the USA and Korea. China and India account for

[6] Valdez, Alberto y Seitz, 1995; World Bank Staff Working Paper, 1986.

[7] Component countries: European Union-15, Australia, Canada, Japan, Korea, Mexico, Switzerland, Turkey and USA.

31 per cent and 22.5 per cent of world production respectively. With the exception of the USA, the European Union, Thailand and Viet Nam, most rice production is focused on meeting domestic demand. The USA exported 49 per cent of its production, Thailand 37 per cent and Viet Nam 16 per cent.

The USA and the European Union deserve special attention in that their per capita consumption in 2000 was about 11.3 kg and 5.5 kg respectively, which is well below the world average of 64 kg, reinforcing the theory that their production is focused on supplying international markets. On the other hand these countries demonstrate a constant trend in the consumption of wheat and its derivates. Indeed, the USA registers a per capita consumption of wheat of about 124 kg and European Union 249 kg, which is considerably higher than the world average of 96 kg.

3.1.2 Subsidies to rice producers in OECD countries

The support provided by developed countries to their agricultural producers is high. In 2001, OECD countries provided US$ 230,744 billion in direct support to producers and US$ 310,959[8] billion in total support. Rice is one of the products benefiting from most subsidies per ton in relation to its international price. While the international reference price for rice[9] in 2000 was US$ 248 per ton, the subsidy per ton in OECD countries was US$ 1,050, i.e. more than four times the international price (OECD, 2001). On the other hand, rice registered a Nominal Protection Coefficient (NPC) of 5.28,[10] meaning that the price paid to OECD producers is 5.28 times higher than the international price, in other words, OECD countries grant their rice producers a nominal protection of 528 per cent (Table 3.1).

The product that receives the highest subsidy per produced ton as measured by the Producer Subsidy Equivalent (PSE) is rice, followed by meat, barley and milk. Figure 3.1 shows the subsidies per product during 2001.

For 2001, aids to rice producers in OECD countries amounted to US$ 29,335 billion, representing 10 per cent of total subsidies for agricultural production in these countries and 32 per cent for total world grain production. These amounts show the magnitude of the subsidies and their impact on prices.[11] The equivalent PSE per ton of rice produced in OECD countries was US$ 1,165 per

Table 3.1: Nominal protection coefficient for Europe, USA and OECD countries, per product, 2000

Product	EU	USA	OECD average
Rice	0.89	1.43	5.28
White sugar	2.39	1.50	2.11
Pork	1.19	1.00	1.18
Chicken meta	1.59	1.00	1.20
Beef and veal	1.89	1.00	1.29
Barley	0.94	1.00	1.34
Milk	1.70	1.90	1.77
Corn	1.08	1.14	1.18
Oilseed	1.01	1.21	1.22
Sorghum	1.00	1.34	
Soybeans	1.00	1.00	1.34
Wheat	1.00	1.15	1.15

Source: OECD, Database 2001.

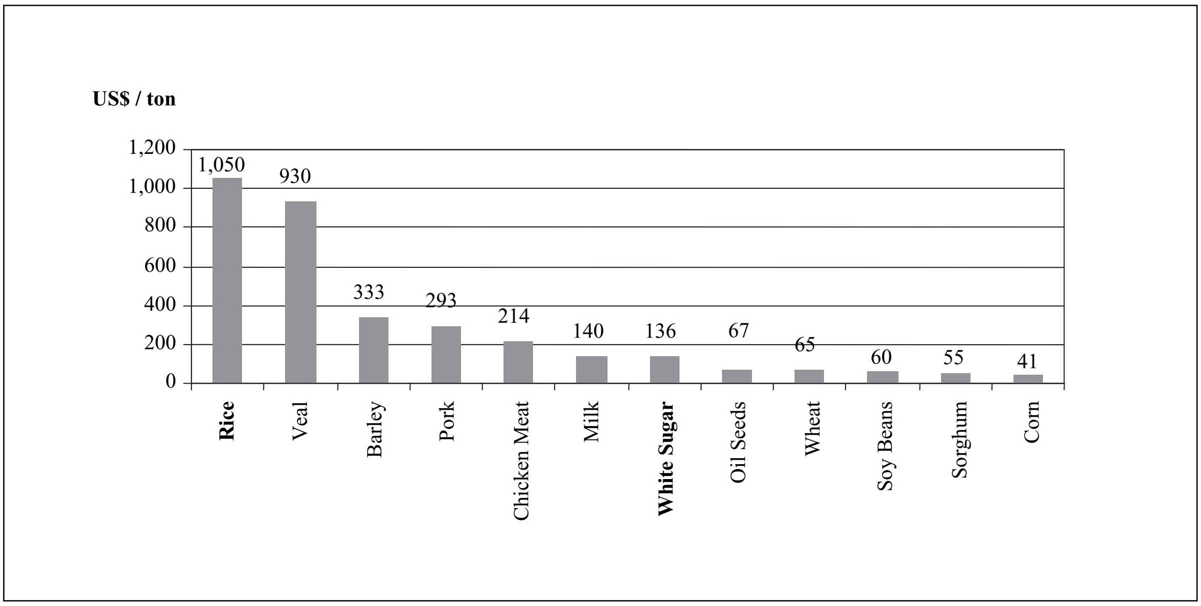
8 General Services not included in the PSE, in OECD, 2001.

9 Refers to CIF Bangkok rice.

10 The NPC is the Nominal Protection Coefficient. If NPC is 1, the international price and the price paid to producers are equal and thus no protection exists.

11 Value of production was calculated as the result of world production in 2001 (380 million of metric tons) time average price US$214. The value was divided by OECD subsidies equivalent to US$ 24.340 billion.

Figure 3.1: Subsidies per produced ton in OECD countries, 2001



Source: OECD, Database 2001.

ton in 2001, i.e. 4.5 times its international price of US$ 214 for the same year, taking as a base the CIF Bangkok price of rice. Supposing that other countries do not subsidize producers, the PSE would be US$ 64 per ton of white rice, i.e. 30 per cent of the international price. This again shows the magnitude of market intervention and the implications that these subsidies have on international prices.

In spite of these considerations, it should be taken into account that production and exports are not only affected by OECD subsidies. Japan, Korea and some non-exporting countries provide considerable subsidies, though other countries such as the USA, the European Union-15, Mexico and Australia grant substantial subsidies as well. In fact, the OECD countries' share of total world white rice production is 5.7 per cent, and just 23.3 per cent of world exports, which indicates that, in spite of the magnitude of their subsidies, other producers and exporters have an important impact on international prices. It is important to note that the magnitude of aids and the share in world markets varies among OECD countries that grant subsidies to rice producers, which redirects the analysis to countries that grant subsidies according to their production volume and share in the world market, since the combination of these variables can determine the impact that a country may have on international markets, especially prices.

The following information on OECD countries was taking from the OECD Database 2001.

Japan is the country that grants most subsidies for rice. In 2001 subsidies amounted to US$ 15,935 billion, i.e. 65.5 per cent of the total amount granted by OECD countries. Despite high production levels (7.7 million tons, 2 per cent of total world production, ninth place among world rice producers), export volumes are insignificant whilst imports are important (9 per cent of total domestic consumption, 656,000 metric tons). On average, for 2001, the implicit subsidy per ton was US$ 2,166, i.e. ten times the international price.

Korea grants the second most subsidies for rice, with US$ 7,244 billion granted, representing 30 per cent of total OECD grants. Korea is an important producer with 4.6 million tons, which represents 1.2 per cent of world production and positions Korea as the thirteenth largest rice producing country. Korea also imports 4 per cent of its total consumption. The implicit subsidy per ton reached US$ 1,546.

Together, Japan and Korea account for 95.5 per cent of subsidies granted to rice producers in OECD countries, but only 3.1 per cent of total production and 4 per cent of world imports. In view of these combined factors, the impact of their subsidies should be minimal in terms of the subsidies per ton and international prices.

However, the impact on the internal production of these countries must be high. If subsidies were to disappear, they would need to cover their demand through imports, which would turn those countries into net importers. In turn this would increase world demand for rice and the magnitude of this increase, which would be exponential to the decrease in production in these countries, would affect international prices.

The **USA** takes third place in terms of subsidies to rice producers with US$ 784 billion in 2001, but occupies first place in terms of world rice production with 6 million tons. The PSE reached US$ 128, representing 60 per cent of the international price per ton of rice. The notable aspect of rice production in the USA, however, is that its production is focused on supplying international markets, since almost 49 per cent of its production is exported, making the USA the fourth largest exporter with a share of 11.7 per cent of total exports.

The **European Union-15** is fourth in terms of subsidies to rice producers with US$ 322 billion in subsidies in 2001, and a production of over a 1.6 million tons of which 1.4 million tons (92.5 per cent) is exported, making this group of countries the seventh world exporter (6.1 per cent of total). The implicit subsidy per produced ton was about US$ 199. However, it should also be noted that the EU-15 is, in fact, a net rice importer with imports of 2 million tons in 2000.

For **Australia,** rice subsidies only amounted to US$ 7 million in 2001 for a production of 805,000 tons and exports of 622,000 tons (55 per cent of production). Implicit subsidies are thus relatively low at US$ 8 per produced ton.

These countries (Japan, Korea, USA, European Union and Australia) grant subsidies of 5 per cent to rice producers, and OECD countries represent 2 per cent of world production and 21 per cent of exports. Given these relationships, the impact of their subsidies should not be high despite their share in exports. Korea, Japan and the EU import at lower prices and consequently have the indirect effect of depressing prices on the international market.

Trends show that producer subsidies per ton of rice in OECD countries were increasing until 1995, but since 1996 they have decreased to 1980s levels. There is also an inverse relationship between the trends of the PSE per ton for production in OECD countries and the international price of rice (Bangkok reference). This relation is most obvious in the case of countries such as the USA, the European Union and Japan. For the USA, there is a particularly strong relationship between subsidies and international prices[12] that relates to the country's subsidy policy of maintaining producers' income, which means the subsidy increases when the price of rice decreases and vice versa.

Besides the connection between these two variables, studies[13] show that subsidies reduce production costs so internal prices are, in fact, higher than world prices. This tends to result in an increase in production but also in exportable surpluses that drive down international market prices.

In conclusion, high subsidies for rice production in absolute and relative terms have impacted international prices in that they bring about a downward trend in the price of rice and cause greater price volatility.

3.1.3 Impact of subsidies on the international price of rice

It is commonly affirmed that, since subsidies granted to agricultural producers have a negative impact on international commodity prices, they also affect world production of those commodities.

[12] Correlation coefficient was -61%.
[13] Valdes and Sietz, 1995.

Since the 1980s, several studies on the effects of agricultural policies in industrialized countries have pointed out that interventionist policies cause international prices to fall below market levels.

Valdez (1995) summarizes the results of some of these studies up to 1995, by comparing international prices for a base year with prices that have not been distorted through government agricultural intervention. He concludes that agricultural policies in developed countries depress international prices significantly. In the case of rice, the effect on international prices of the application of such policies varies between -2 per cent[14] and -43 per cent (UNCTAD-WIDER). The difference originates from the base year used for analysis and the level of liberalization assumed in each of the referenced documents.[15]

Consequently, in countries that are unable to finance producers through domestic aids or export subsidies and maintain low protection levels at borders or in which administrative controls are insufficient, production, cultivated areas, incomes, employment and other variables will be affected. Meanwhile, developed countries that regulate the market tend to over-produce and generate exportable surpluses that depress international prices.

Estimations of the impact on international prices of subsidies granted to rice producers in developed countries cannot be realized immediately given the existence of important substitution relationships in cereal consumption, mainly between rice and wheat. As will be shown later in this study, there is an equilibrium relationship over the long term in the prices of these two commodities. It is thus necessary to also take into account the impact on rice prices of subsidies to wheat producers. In the case of Latin America there are several studies that prove this substitutability.[16]

The core question is: what is the level of the impact of international production-related subsidies on international prices? To establish this relationship, a model was developed to estimate the relationship between the international price of white rice and subsidies to rice producers in OECD countries and the international price of wheat.[17] The estimation was calculated using panel data for the period 1986-2000. This econometric model should be understood as a combination of time series and cross-section data. The panel data includes information for six OECD countries that grant subsidies to rice producers, namely the USA, Mexico, Australia, Japan, Korea and the European Union.

A lagged dependent variable was included as an explicative variable, and it is supposed that current prices would determine future prices, obligating the use of a dynamic panel. In general terms, the following equation was estimated:

$$P_{i,t} = n_i + ap_{i,t-l} + \beta X_{i,t} + v_{i,t}$$

where P corresponds to the international price of rice, X is a vector containing other explicative variables, is a constant capturing differences among countries, and is an error.

Data from different variables were standardized, so its mean was rested and divided over its standard deviation with the objective of eliminating heteroscedasticity problems on the error due to the differences among the variables from different countries.

For interpretation, it is important to take into account that the resulting estimations measure the impact of the surnamed variables over the international price of rice in terms of the standard deviation of each one, so a transformation of parameters is required to interpret results in terms of changes. Results are presented in Table 3.2. As expected, the international price of rice corresponds positively to its lagged value and to the price of wheat, and on the other hand it has an inverse

14 Valdez and Sietz, 1995.
15 Ibid., pp 913-926.
16 Ramírez Tolosa, 2002; Martínez Covaleda, 1999; Abreau y Ablan, 1993; Byerlee, 1976.
17 For international rice and wheat prices, the CIF Bangkok and CIF Wheat Hard Red Winter No 2 prices have been used. Production database from FAO, 2000.

Table 3.2: Summary of the results from the model to explain price formation on the international rice market, 1986-2000

Dependent variable	Constant	Rice (-1) international price	Wheat international price	World rice production	PSE/ton for the rice
Rice international price	0.0321164	0.281531	0.619201	-0.257307	-0.168245
P-value	0.000	0.000	0.000	0.000	0.001

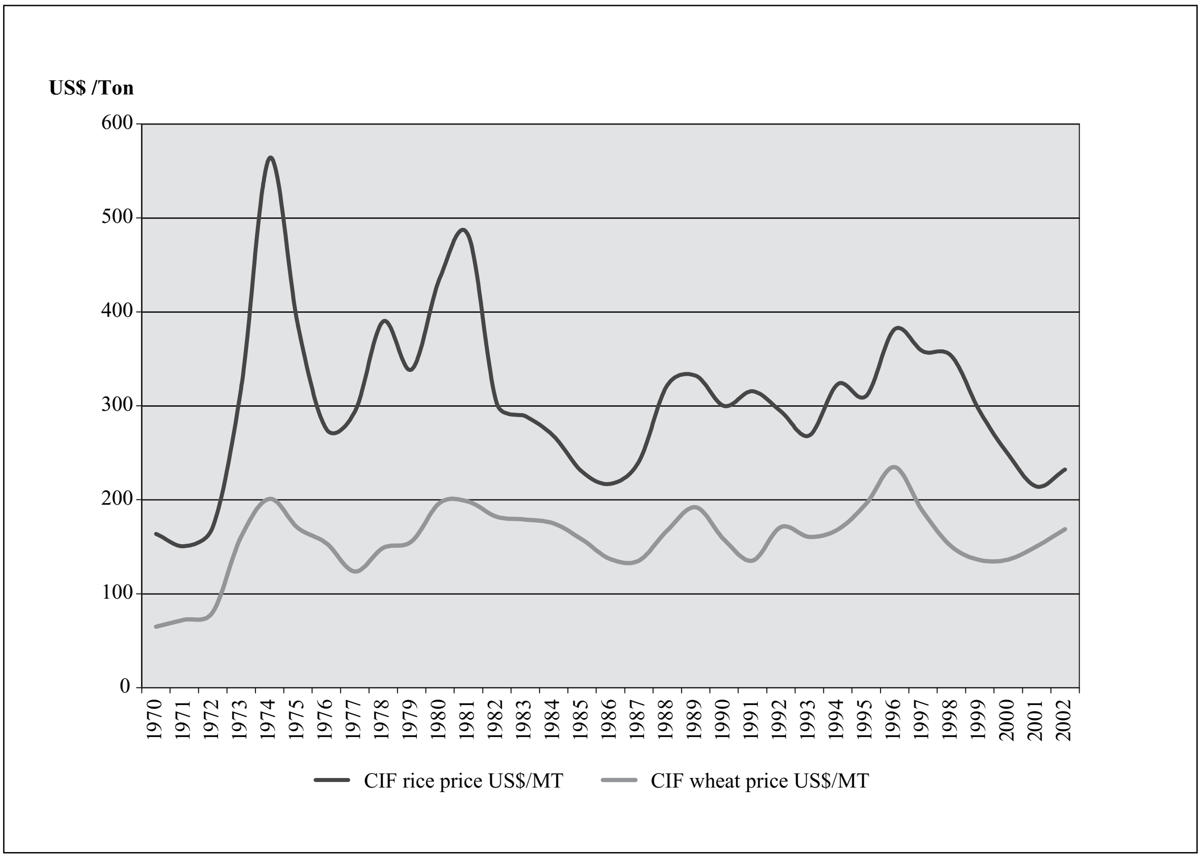
Confidence coefficient of error at 5 per cent.
$R^2 = 0.7091898$
P-Value Wald (joint) 0.000
P-Value Wald (dummy) 0.000

Source: Subsidies OECD, Production FAO's Database, Prices Rice Bangkok – FEDEARROZ, Wheat prices Hard Red Winter No.2, Ministry of Agriculture.

relationship to the total amount of rice produced around the world and to the subsidy.

As observed, in terms of standard deviations, the trend for the international price of wheat is the variable that explains most of the movements in the international price of rice and shows that the prices of rice and wheat follow the same direction, so if there is a decrease in the price of rice, there is also a decrease in the price of wheat, but to a lesser extent. Figure 3.2 compares the fluctuations in the international price of rice and wheat over time, demonstrating the link between these two variables.

Figure 3.2: International prices of rice and wheat, 1970-2002.



Source: Ministry of Agriculture and FEDEARROZ.

Table 3.3: Changes in international rice prices in the case of a total or partial (50 per cent) reduction on subsidies in OECD countries, 2000

	Total elimination of PSE/ton			50% reduction of PSE/ton		
	Start prices	Final price	Change %	Start price	Final price	Change %
European Union	246	246.1	0.04	246	246.0	0.02
Australia	246	246.0	0.01	246	246.0	0.00
Japan	246	275.1	11.82	246	260.5	5.91
Korea	246	257.6	4.71	246	251.8	2.36
Mexico	246	246.1	0.02	246	246.0	0.01
USA	246	247.1	0.45	246	246.5	0.22
Total OECD	246	287.9	17.04	246	267.0	8.52

PSE/Ton is the subsidy percentage in rice, per ton.
Source: PSE/ton Database OECD 2001.

Subsidies to rice producers only provide a small part of the explanation of international rice prices. Thus, if these subsidies increase one standard deviation, the international rice price reduces the standard deviations by 0.168. In dollar terms, this relationship suggests that if the PSE increases by US$ 233 per ton, the international price of rice reduces by US$ 9.3 per ton.

If we assume a total abolition of the subsidy in OECD countries (US$ 1,050 per ton in 2000), and other variables remain constant, the international rice price should increase by US$ 42, i.e. a 17 per cent increase with respect to the price observed for 2000 (US$ 246) (see Table 3.3). If we assume a direct transfer to the national price, an increase of the internal price of this magnitude (17 per cent) would imply an increase on the Colombian rice production of about 18.4 per cent (426,782 tons and 88,913 hectares).[18] On the basis of a more pessimistic reduction of 50 per cent of the subsidy in OECD countries (US$ 525 per ton), the international price would increase by US$ 21, i.e. an increase of 8.5 per cent in relation to the price of rice in 2000.

Taking only the case of the USA, a total abolition of subsidies would result in an increase of the international price of US$ 1 (0.45 per cent), and a reduction of 50 per cent in subsidies per ton would increase the international price by only 0.22 per cent in relation to prices in 2000. In comparison, total or partial abolition of subsidies granted by Japan and Korea to rice producers would have a major incidence on the international price of rice; the elimination of subsidies in these countries

Table 3.4: Summary of the model explaining the relationship between international rice prices and international wheat prices, 1986-2000

Dependent variable	Constant	Wheat (-1) international price	Wheat world production	Wheat PSE/ton
Wheat international price	-0.0915525	0.683801	-0.501542	0.178331
P-value	0.000	0.000	0.000	0.078*

**Significance 8%*
R^2 = 0.5380313
P-value Wald (joint): 0.000
P-Value Wald (dummy): 0.000

Source: Production FAO's Database, Wheat price Hard Red Winter No. 2 Ministry of Agriculture, PSE OECD Database 2001.

[18] Here we assume a paddy rice production for 2001 of 2,313,811 tons, a yield of 4.8 tons dry paddy per hectare and a price elasticity of 1,085, estimated by Observatorio Agrocadenas from Agriculture Ministry and Desarrollo Rural de Colombia.

Table 3.5: Changes in the international price of wheat with a partial or total abolition of producer subsidies in OECD countries, 2000.

	Total elimination of PSE/ton			50% reduction of PSE/ton		
	Start price	Final price	Change %	Start price	Final price	Change %
European Union	134.9	144.6	7.2	134.9	139.7	3.6
Australia	134.9	136.7	1.4	134.9	135.8	0.7
Japan	134.9	137.5	1.9	134.9	136.2	1.0
Mexico	134.9	136.8	1.4	134.9	135.8	0.7
USA	134.9	142.1	5.4	134.9	138.5	2.7
Total OECD	134.9	151.4	12.2	134.9	143.1	6.1

Source: PSE/ton Database OECD 2001.

would imply an increase in international prices of 11.8 per cent and 4.7 per cent respectively. On the whole, as estimated coefficients show, the magnitude of the effect of total or partial elimination of subsidies is not as important as might be expected because of the low share of OECD countries in world markets.

In view of the strong substitution relationship between rice and wheat and the effect of wheat prices on rice prices, the same exercise was applied for wheat. The results are shown in Table 3.4.

As expected, the international price of wheat responds positively to its lagged value, and negatively to changes in production levels and subsidies. As for the previous exercise, the series were standardized so the results must be interpreted in terms of standard deviations from the originals. In this sense a reduction of one standard deviation on the PSE per ton would increase by 0.17 the standard deviations from international prices for that product.

As observed in Table 3.5, total elimination of subsidies granted to producers in OECD countries would increase international quotations by about 12.2 per cent, which means that the price per ton of wheat would increase from US$ 134.9 to US$ 151.4. If the reduction in the subsidy per ton were 50 per cent, the international wheat price would increase by 6.1 per cent. The greatest effects would originate from the reduction or elimination of subsidies by the European Union and the USA.

Applying these results to the rice equation shows an additional increase of 6 per cent on the price of rice as a result of the higher price of wheat on international markets. Consequently, the elimination of rice subsidies has greater implications on the price of rice (17 per cent) than the increase of the price of wheat resulting from the elimination of subsidies on the latter. This means that complete elimination of OECD subsidies for both rice and wheat would cause the international prices of these grains to increase by about 17 to 23 per cent.

In summary we can make the following affirmations:

- Rice subsidies in OECD countries affect international prices inversely, i.e. the higher the subsidy, the lower the international prices.
- The magnitude of the impact of subsidies on the price of white rice is not as important as expected; a complete abolition of subsidies in OECD countries results in a 17 per cent increase in the price because OECD countries only represent 5 per cent of world production and 21 per cent of total exports.
- Despite the fact that the USA and the European Union are important rice producers and exporters, the elimination of subsidies in these countries alone would have less effect than the elimination of subsidies in OECD countries, Japan or Korea, which shows that the USA and the European Union do not define international prices, and their subsidies are in fact just one of the variables, perhaps even one of the least important, defining international prices.
- The abolition of rice subsidies has a greater effect on the price of rice than an increase in the price of wheat resulting from the elimination of

wheat subsidies. So if the price of wheat increases by 12.2 or 6.1 per cent as a result of the elimination of wheat subsidies, all else being equal the price of rice would increase by 6 or 3 per cent respectively.

- If we assume an increase of 17 and 23 per cent in domestic prices as a result of the combined effect of eliminating subsidies on both rice and wheat in OECD countries, paddy rice production would increase by about 426,782 and 577,411 tons respectively, representing an increase in production of 18.4 and 25 per cent respectively. At current yield levels (4.8 tons of dry paddy per hectare) this would represent 88,913 and 120,294 additional hectares respectively.

3.1.4 Relationship between international and Colombian prices

Economists specialised in trade have been discussing the positive and negative aspects of protections in certain economic sectors based principally on the income generated within their product chains. Certain protections were applied to the Colombian rice sector during the period of economic openness as described previously. Nevertheless, prices have decreased by 38 per cent in real terms over the last 12 years, and costs, which affect producers' incomes, have followed a similar trend. Producers question why, despite protections, internal prices have decreased so much. Furthermore, if both national and international prices have followed the same trend, what would have happened if protections had isolated domestic prices from international fluctuations? Several hypotheses appear to explain this phenomenon. One involved analysing the possible long-term relationships between the international prices of wheat and rice, and between the import cost of wheat and the price of Colombian rice.[19] The analysis that follows seeks to shed some light on the transmission mechanism of international prices on domestic prices.

3.1.4.1 Long-term relationship between domestic and international prices of rice and wheat

The first approach is to consider the long-term trends of the price of rice in terms of the international CIF price in US dollars and the price of Colombian paddy in US dollars. As can be seen from Figure 3.3, there is a strong relationship in terms of volatility and trends between the two prices, albeit at different scales.

The second relationship that can shed some light on rice price trends is by comparing the latter to the price trends of wheat. As for Figure 3.2 which shows international price trends for wheat and rice for the period 1970-2002, it is again apparent in Figure 3.3 that there is a strong correlation in volatility and trends, albeit at different scales. Volatility in the price of rice was very high during the 1970s, but was less so from the 1980s onwards. It can also be seen that, over the last couple of years, the gap between wheat and rice prices has been decreasing.

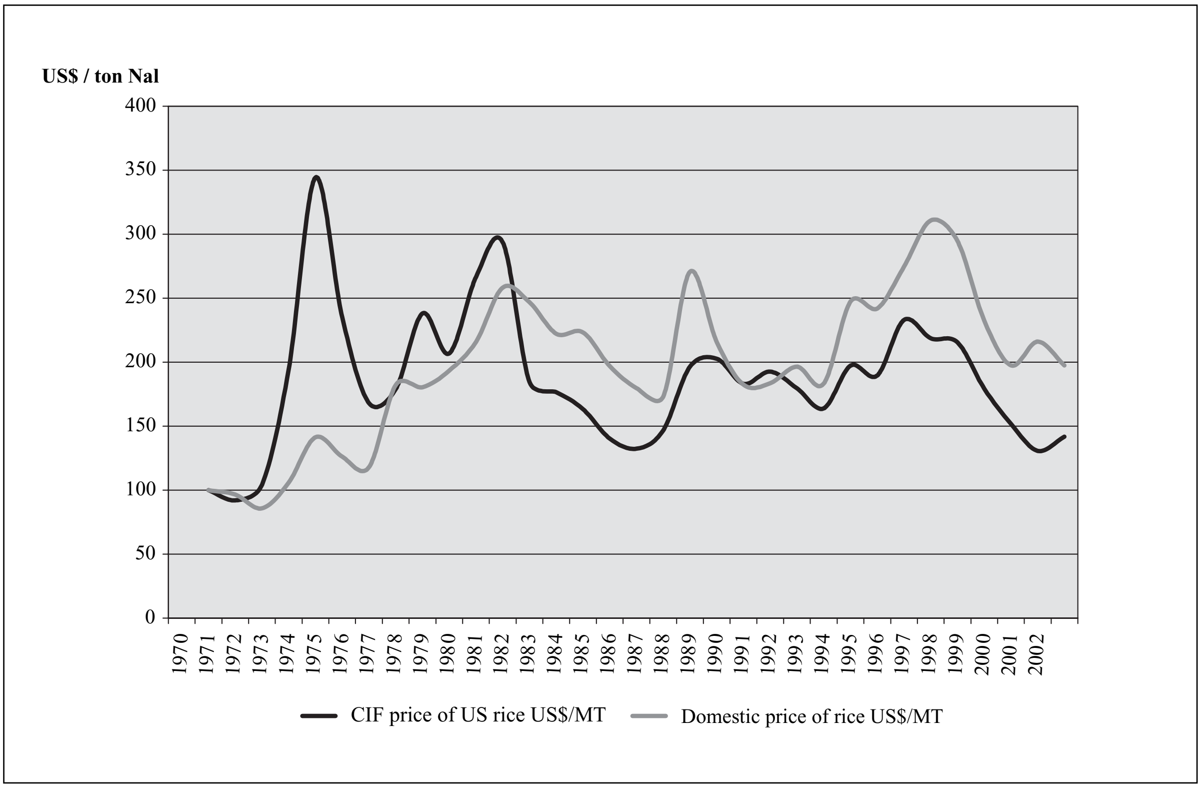
The next relationship to be considered is that between the international price of wheat and the domestic price of Colombian paddy, both in US dollars. Again, Figure 3.4 shows a distinctive symmetry in the trends of domestic paddy prices and international wheat prices since 1976.

From this graphic analysis it could perhaps be inferred that there is a close relationship between international rice and wheat prices and the price of Colombian paddy rice, since during the 1990s these relationships become symmetric. However, these relationships do not necessarily imply causality.

To verify any actual causality relationship between national and international rice prices, a co-integration analysis was performed, with a null hypothesis in terms of the existence of long-term relationships between the variables. This exercise was carried out to test the relationship between the price of

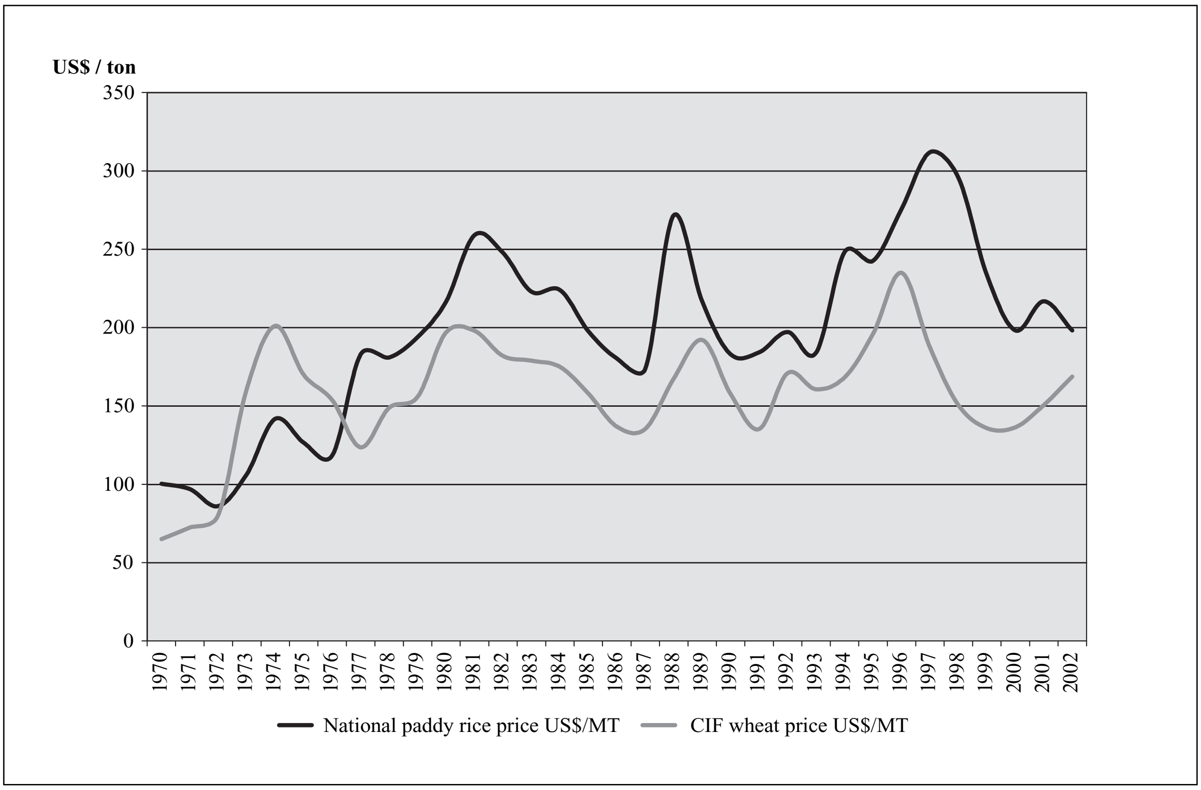
[19] The international rice price corresponds to white rice 100% B. CIF Bangkok, with 10% of broken grains. The international rice price corresponds to CIF Hard Red Winter No 2. The national price corresponds to best quality rice. All prices in US dollars per ton and were deflected by the USA Price Consumer Index.

Figure 3.3: CIF price of US rice and domestic price of rice, 1970-2000 (in US dollars)



Source: Ministry of Agriculture and FEDEARROZ.

Figure 3.4: National paddy rice price and international wheat price, 1970-2002



Source: Ministry of Agriculture and FEDEARROZ.

Table 3.6: Cointegration relationship – Johansen Test

	H_0: Numbers of cointegration vectors	Verisimilitude ratio L-Max	Critical values L-Max	Traza	Critical Value Traza 90
Cimt-Arnal	Nothing	19.86	22.95	24.80	12.39
	Maxim once	4.95	10.56	4.95	10.56
Acif -Tcif	Nothing	11.25	10.60	14.40	13.31
	Maxim once	2.15	2.71	2.15	2.71

Cimt: Import costs of wheat.
Arnal: The domestic price for rice.
Acif: CIF prices of rice.
Tcif: CIF prices of wheat.

Colombian rice in US dollars and the international wheat price, and between the international prices of rice and wheat to verify any possible substitution relationships. A co-integration relationship between the variables mentioned above shows that the perturbations or shocks do not only have a temporal effect over the variables, but a permanent effect.

Time-series exercises were carried out on the observed quotations for rice (CIF Bangkok) and wheat (Hard Red Winter #2 from the USA) for the period June 1991 to October 2002, and on the tariffs from the price bands for each of these products. Data were deflected with the USA CPI, so comparisons are in constant terms.

Using the Dickey-Fuller test, the analysis results showed that the CIF prices of rice and wheat, import costs of wheat and the domestic price for rice have a unit root, so they are co-integrated. To reinforce this hypothesis a KPSS test was calculated, confirming the results of the first test.

Once the existence of a unit root was determined for each variable, a co-integration test was performed to determine if movements among variables tend to converge in the long run. Results of the exercise confirm the existence of co-integration between the import cost of wheat and the domestic price of rice, and between the international CIF prices of rice and wheat (see Table 3.6).

This means that the price of Colombian rice and the import cost of wheat display a long-term equilibrium relationship, as do international prices of rice and wheat. Any variation in one variable will cause the other variable to move in the same direction, maintaining the equilibrium relationship.

3.1.4.2 Relationship between rice and wheat prices

So far a strong relationship between Colombian rice and international rice prices has been tested, and also among Colombian rice prices and imported wheat prices. The question is why do these relationships occur given the isolation process of Colombian rice production for the last 12 years?

A possible explanation, and maybe the most effective one, is given through the products consumed in substitution to rice. Indeed, several studies have emphasized the existence of a strong substitution relationship between the human consumption of rice and wheat derivatives,[20] and empirical evidence proves this association. A review of the per capita consumption for rice and wheat for 210 countries based on data from the FAO[21] shows that, between 1991 and 2000, 50 per cent of the selected countries were below the average of the 210 countries. As can be seen in Table 3.7, for the period 1990-2000, most countries show a high negative correlation between rice and wheat consumption,

[20] Ramírez Tolosa, 2002; Martínez Covaleda, 1999; Abreau and Ablan, 1993; Byerlee, 1976.

[21] Per capita consumption for all countries reported by FAO was calculated for 1990 and 2000. Data in tons were taken for imports, exports, production, and apparent consumption. These amounts were divided by the annual population reported by FAO. Rice production in terms of white rice.

Table 3.7: Share of rice and wheat consumption by country, 1961-1970, 1990-2000

1961-1970

Consumption pattern versus World average	Country Total	Percentage	% excluding poor countries Under world average
1. Less rice, less wheat	131	62%	
2. More rice and less wheat	35	17%	44%
3. More rice, more wheat	0	0%	0%
4. Less rice more wheat	44	21%	56%
Total	210	100%	79

Source: FAO Authors

1990-2000

Consumption pattern versus World average	Country Total	Percentage	% excluding poor countries Under world average
1. Less rice, less wheat	104	50%	
2. More rice, less wheat	35	17%	33%
3. More rice, more wheat	2	1%	2%
4. Less rice more wheat	69	33%	65%
Total	210	100%	106

Source: FAO's Database 2000.

with 65 per cent of the sample countries registering a high consumption of wheat and low consumption of rice and 33 per cent registering high consumption of rice and low consumption of wheat.

The data shows that countries with high per capita wheat consumption with respect to the world average also demonstrate low per capita rice consumption, suggesting an inverse relationship among these grains. However, this still does not necessarily imply causality. Table 3.7 also suggests that some changes have occurred in terms of the consumption patterns of these grains over time. For the 1961-1970 period only 44 countries registered a higher consumption of wheat than rice (in relation to the world average), which increased to 69 during the 1991-2000 period, while those maintaining a per capita consumption of rice higher than wheat remained constant at 35. Countries that increase wheat consumption substitute rice for wheat.

Several empirical studies for Colombia have shown the important substitution effect of wheat derivatives and white rice consumption. The most recent study was made for the "Comité de Seguimiento a la Competitividad del Arroz" in 2000.[22] Before presenting the results of this study, it should first be remembered that Colombian wheat prices follow international prices very closely, taking into account the fact that imports are regulated by the Andean agricultural price band system for wheat.[23] As already observed in Figures 3.3 and 3.4 above, the relationship between the price of imported wheat and the price of Colombian rice is relatively high (48 per cent with no lags). However, as proved later, price transmission does not occur simultaneously, but rather it converges in the long run via consumption substitution. The results of the study mentioned above are presented hereafter.

The first fact to determine in the aforementioned study was whether a relationship existed between the domestic price of white rice and its substitutes, namely wheat derivatives, maize flour and potatoes, as measured by the CPI index from 1991 to 2002. By this method, the hypothesis of the long-

[22] Ramírez, 2002.

[23] The correlation coefficient among the CIF price and import cost is high (75 per cent). Notwithstanding, national wheat represents only 4 per cent of rice consumption.

term equilibrium is tested through a co-integration analysis using the Johansen methodology. If the consumer prices of white rice, pasta, bread, potatoes and maize flour maintain an equilibrium relationship, a linear combination of them would present a trend that would converge to an equilibrium value in the long run if the effects on the economy are only temporal.

In the first place, the Dickey-Fuller test evidenced that the price series had a unit root; the prices were non-stationary, meaning that individually the prices do not converge to a value in the long run, and shocks on these prices would have permanent effects making their long-term movements unpredictable. Furthermore, this series had a deterministic term. But although individual prices are not stable in the long run and alterations of these prices may last a long time, it can happen that their combination within a market tends towards a long-term equilibrium, eliminating shock effects and generating a joint relationship that makes relative prices move in the same direction within the market.

To test this hypothesis a Vector Auto Regressive (VAR) model was estimated using Akaike, Schwarz, and Maximum Likelihood (ML) criteria and serial correlation tests to determine the appropriate lag number. The test suggested two and three lags. This exercise used three lags since it guarantees no serial correlation problems.

Finally, the Johansen test was performed to determine if price indexes maintain a joint relationship in the long run. It was found that price indexes do maintain a long-term relationship in the market, and that series are co-integrated. This way, although individual prices showed a positive linear trend, it is not possible to eliminate price shocks in the short run and any equilibrium deviation can be eliminated.

Concretely, results indicated two possible co-integration relationships among the five price indexes, which means that, in the long run, eventual price shocks of the mentioned products would be temporal and would tend to adjust over time. Furthermore, any alteration of the price of any of the goods would cause the others to move in the same direction towards equilibrium.

The second part of the exercise consisted in estimating the magnitude of the substitution effect among these products, so a determination model for wheat and its substitutes was calculated. The exercise was carried out using an annual series for the period 1961-2001 for the following variables:

- per capita consumption and real prices of white rice, maize for human consumption, and potatoes in kg and constant pesos per kg (2001 prices)
- per capita GDP (2001 prices) as a measure of income
- real Foreign Exchange Index weighted by the Producer Price Index with base year 2001 as a measure for foreign trade policy.

A model of long-term demand equations was designed to calculate the average elasticities of consumption with respect to the imported wheat price, product prices, income, and foreign exchange policy. These equations are approximated to conventional demand equations that include the price of the good and its close substitutes, consumer incomes and foreign exchange policies. Equations are specified in per capita consumption terms to take into account population changes. In the same way, the income measure selects the effects of changes in the economic structure of the country.

In theory, changes in income modify food preferences, while price changes modify consumption decisions between close substitutes based on the budget of a typical consumer. Products in this study have a high import component in terms of costs and external demand; real foreign exchange affects the decisions of importers and product prices.

It is convenient to specify that wheat, its derivatives and substitutes form a market in which the components are interrelated based on the consumption distribution of each good within households. In fact, as explained earlier, the prices of these products have a long-term relationship in that they evolve over a temporal convergent path making perturbations short lasting and transitory. This implies that demand equations are dependent on each other and, consequently, their estimation should be simultaneous to avoid biases in the calculus of elasticities.

Table 3.8: Estimations of price elasticities for rice, wheat and potatoes

Dependent variable	Real price rice	Real price wheat	Real PIB per capita	Real exchange indices	Real price corn	Real price potato	Dummy 1990	R^2	R^2 adjust
	Explicative variables */								
Per capita rice consumption									
Elasticities	-0.94	1.16	1.99	-0.84				0.641	0.6126
t test	-4.5744	5.526	11.987	-4.272					
Per capita wheat consumption									
Elasticities		0.87			-0.33		0.12	0.646	0.6168
t test		6.2013			-2.3300		1.9801		
Per capita potatoes consumption									
Elasticities		0.41	2.09	-0.78		-0.22		0.849	0.8325
t test		6.314	11.80	-3.8920		-2.9117			

*/ t test shows significance at 94% level
Residuals first order autocorrelation test:
Equation 1: serial correlation-Q (LM)= 1.6126 Prob>Q=0.2041
Equation 2: serial correlation -Q (LM)= 0.2263 Prob>Q=0.6342
Equation 3: serial correlation -Q (LM)= 1.3525 Prob>Q=0.2448

Source: FEDEARROZ, Ministry of Agriculture and Central Bank.

The purpose of this exercise was to quantify the price elasticities of rice, maize for human consumption and potatoes, to obtain the substitution parameters between rice and wheat. Equations were estimated linearly using the Feasible Generalized Least Squares method in two stages. The results are presented in Table 3.8.

The advantage of simultaneous estimations is that parameters are estimated jointly due to the interrelation between variables. This way rice market perturbations affect not only the price of rice but also other prices, thereby procuring statistic efficiency and confidence in results. In particular, estimated parameters resulted in the expected signal, and elasticities were significant, i.e. at levels around 94 per cent.

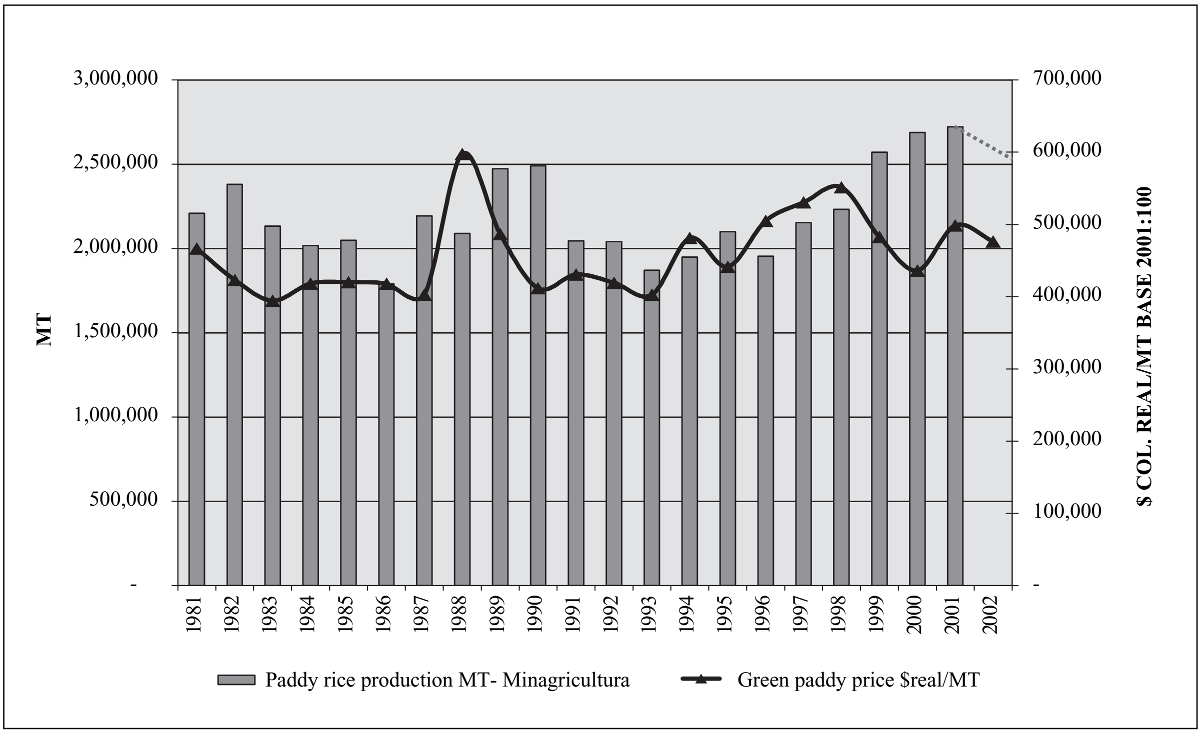
As expected, the equation for rice showed that per capita rice consumption was altered by the real price of wheat. In fact, the signal of the price elasticity of rice with respect to wheat is positive, implying that a reduction in the real price of wheat would cause a reduction in the per capita rice consumption and vice versa. The causality is as follows: a reduction in the price of imported wheat increases the per capita consumption of wheat and at the same time households reduce their rice consumption, since wheat derivatives become cheaper in relative terms. This result confirms the substitution hypothesis between rice and wheat.

The substitution elasticity between rice and wheat for the period 1961-2001 is about 1.16 so a reduction of 1 per cent in the price of wheat would cause a 1.16 per cent decrease in the consumption of white rice per capita.

On the other hand, and as expected, rice demand reacts inversely to its price. Price elasticity for rice demand was –0.94 for the same period, so the per capita consumption of rice is elastic to price. Per capita GDP directly influences rice demand with an elasticity of around 2, so it can also be said that rice demand is elastic to income changes. In addition, per capita rice consumption also reacts directly to the real appreciation or depreciation of the peso, because a reduction in foreign exchange encourages wheat imports.

In summary, white rice prices are conditioned to the changes in the price of imported wheat. If those prices are conditioned to subsidies, then Colombian rice prices are conditioned by rice and wheat subsidies.

Figure 3.5: Production and green paddy price in Colombia, 1981-2002



Source: Ministry of Agriculture and FEDEARROZ.

3.1.4.3 Effects of international prices on the Colombian rice sector

As shown before, international rice and wheat prices have suffered an important reduction, partly because of subsidies in OECD countries. Over time this negative trend has been transmitted to domestic rice prices.[24] However, price reductions have been mitigated as a result of other variables that jointly explain changes in cultivated areas, production, employment and producers' income. This section identifies the magnitude of these effects.

Impact of international prices on rice production in Colombia

As discussed earlier, rice demand is explained by the combined effect of income, substitute prices and its own price.

As Figure 3.5 shows, in general, a reduction in prices causes a decrease in production with some lag, and vice versa. In fact, the price elasticity of production in the long run for the period 1980-2001 was calculated to be 1.14, indicating that Colombian rice supply is very elastic. Thus, production increases or decreases proportionately more than the increase or decrease in producer prices.

Until 1990, production increased as a result of a set of economic measures to stimulate producer prices, known as “selective supply”. Between 1988 and 1989 prices increased extraordinarily, and the effects of this increase translated into an increase in production until the 1990s.

With the implementation of economic openness, imports were liberalized, which resulted in a drop in prices, although the implementation of Price Band Systems for white rice and wheat since mid-1991 (a Colombian Price Band System in 1991 and an Andean one in 1995) prevented international rice prices from affecting domestic producers, serving as a stabilization mechanisms for food imports.

From 1991, wheat imports were subject to a harvest absorption policy and to tariffs from the

[24] The domestic price of rice is affected by the price of wheat via substitution.

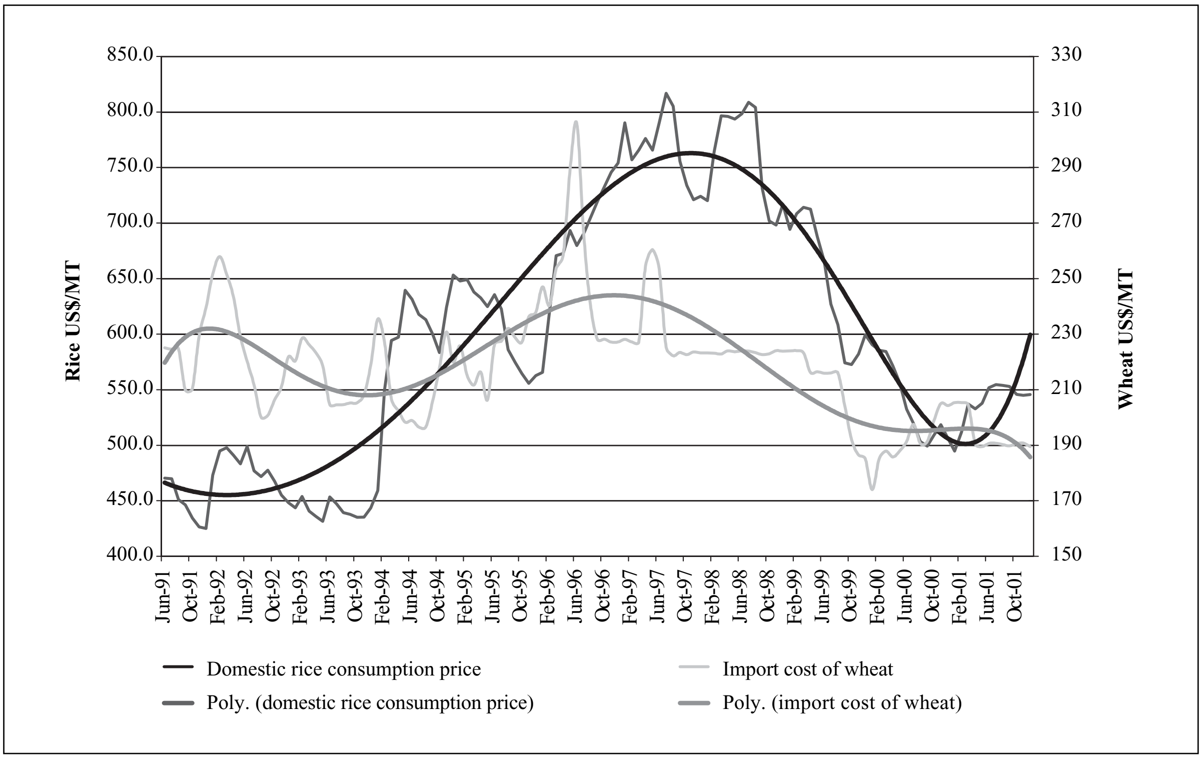
price band system. Rice was also subjected to this system and to a series of measures applied to avoid the immediate transmission of international prices into domestic prices, which works as in a closed economy, except for the changes of the cost of imports for substitute goods and variations in the exchange rate.

From 1993 to 1998 international prices for white rice and wheat registered an important increase, placing them above the average of the last decades (see Figure 3.6). Between June 1993 and July 1998 the international price for white rice increased by 61 per cent while the domestic price increased by 77 per cent in constant terms. This again shows that an increase in international prices pushed up the domestic price. Production also increased notably.

However, per capita consumption also increased from 29 kg to 43 kg, partly because of imports (by 1998, 19 per cent of rice consumption was met through imports). This price and consumption increase was not expected because of a demand elasticity of –0.94. However, price is just one of the variables influencing consumption.

From July 1998 to December 2002 rice prices fell sharply (-49 per cent in constant terms), compared to the international rice quotations of -41 per cent.[25] This price decrease increased internal demand and production. Since the import cost of wheat remained constant, and the domestic price of rice decreased, relative prices were favourable for rice, which explains the short-term increase in demand (see Figure 3.7). Without the price band system, domestic rice prices would have reacted differently. The price decrease should not have induced producers to increase production, but in fact there was an increase in the harvested area of 78,000 hectares (19 per cent) and in production of 415,000 tons (22 per cent). This is explained by the reduction in production costs[26] per hectare and per ton due the yields increase.

Figure 3.6: Monthly domestic rice price and import cost of wheat, 1991-2003

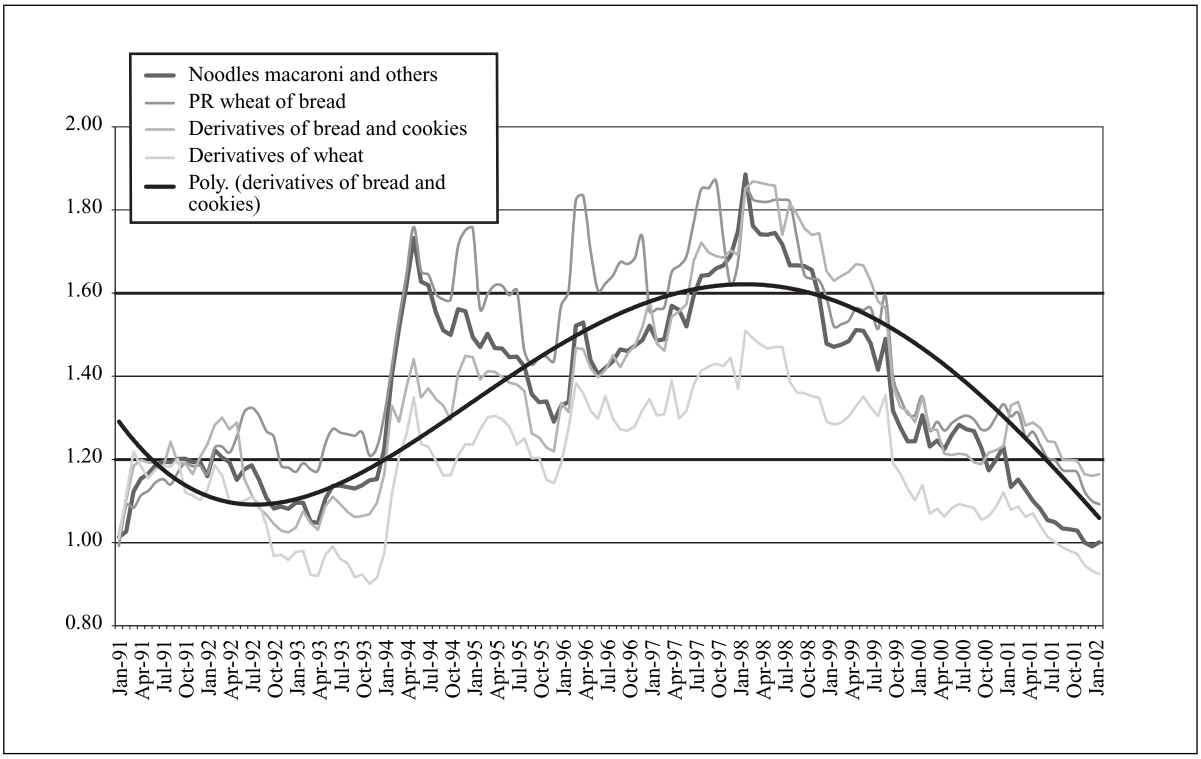


Source: Ministry of Agriculture and FEDEARROZ.

25 Figures in US dollars.

26 Between 1998 and 2001 real costs decreased by 4.4 per cent while prices decreased 4.1 per cent.

Figure 3.7: Relative prices of wheat derivatives and rice prices, 1991-2002



Source: Ministry of Agriculture.

In summary, it can be affirmed that, given the relationships among international quotations (which are conditioned by international subsidies) and domestic rice prices, the decrease in the price of rice stimulated per capita consumption of rice. Furthermore, the decrease in prices was more than compensated by the decrease in production costs, and since the profitability of rice production was not affected, it stimulated production.

Effects of international prices on Colombia's trade balance

Colombia was a net rice exporter until 1991 when exports totalled 85,000 metric tons, representing 8.1 per cent of domestic consumption. From the following year, however, the situation changed, and the rice trade balance has been negative ever since. The largest imports were recorded between 1994 and 1998 (see Table 3.9). This last year (2002) imports were about 19 per cent of consumption. Most imports originate from Ecuador and Venezuela (CAN members), and imports would have continued to increase had no safeguard existed in 1998.

The cost in terms of foreign exchange of becoming an importer has been about US$ 281,353 million. During the last year alone, rice imports totalled 61,400 metric tons, representing US$ 18.8 million.

3.2 Social impacts

3.2.1 Employment generated by rice cultivation

Rice production has a strong socio-economic component. In most of the producer zones rice is the main activity for the rural and urban population. Rice cultivation contributes favourably to employment generation in the communities concerned and to labour absorption in agro-industrial activities in general. Industrial and commercial activities generate employment as well as demand for construction materials, services, consumer products, transportation, raw materials and inputs. Most of these activities relate to the development of the crop production and are considered of great importance.

Employment generated by rice production increased by 0.3 per cent annually between 1987 and 2001. By 1997 54,789 new jobs had been generated, and by 2001 that figure reached 69,020. Employment trends are tied to the evolution in production, which in turn is conditioned by changes in relative prices of wheat derivatives, income and the exchange rate. Supply, on the other hand is conditioned by costs, production and, hence, employment.

From 1997, as long as production continued to increase, employment responded in the same way. The increase in the harvested areas during this period was not related to a price increase but rather to a reduction in costs, which allowed greater profitability from rice production and an increase in employment and production.

Whilst rice production itself has generated employment, the main impacts are based on economic activity within the zones where rice is produced. The multiplier factor originating from this activity is important for income generation in tropical Colombian zones. Nearby cities depend almost entirely on rice-related activities; in particular input trading, banking, mechanical workshops, markets, urban and rural transportation, health services, oil trading, etc. all depend directly on rice production. When it is said that imports of cheaper goods to Colombia benefit consumers, the overall rice community must be taken into account because a reduction in purchasing power in that community would imply a loss for a vast number of people.

3.2.2 Effects on the community

Rice cultivation also energizes local and regional development in other related activities. It has been observed that family labour is heavily used in dry land systems that are characterized by low hectarage and low mechanization. The organization of the community is reflected in the development of the activities employing workers in land preparation, infrastructure construction, civil works such as drainage systems, and transport of materials. However a strategy has not yet been developed for civil participation in decision-making related to agro-industry development and to ensure sustainable approaches to protection and conservation of the atmosphere and natural resources.

3.2.3 Land resources

Production is mainly affected by land prices and use, especially in cases where the land is adapted for water channelling and irrigation, causing a change in the value per hectare depending on the production area and cultivation system.

Land has become a form of low-risk investment since its value continues to increase. Because of this the majority of rice producers (54.1 per cent) rent land instead of owning it, which has a number

Table 3.9: Main economic indicators for rice in Colombia, 1991-2001

Year	Production (ton)	Imports (ton)	Export (ton)	Trade Balance	Apparent Consumption (ton)	Per capita Consumption (kg/per capita)	CAN's Imports (ton)	CAN's Exports (ton)
1991	1,130,090	249	84,509	84,260	1,045,830	29,3	150	70,485
1992	1,127,718	68,766	450	-59,612	1,187,330	33,3	34,931	450
1993	1,033,540	31,094	3,666	-30,222	1,063,762	29,8	33,877	3,661
1994	1,077,188	210,566	2,290	-223,147	1,300,335	36,4	80,418	219
1995	1,159,995	100,817	294	-101,712	1,261,707	35,4	79,417	293
1996	1,079,857	167,9547	47	-131,700	1,211,557	34,0	113,239	10
1997	1,189,686	148,739	172	-165,896	1,355,582	38,0	138,774	160
1998	1,233,590	265,028	346	-288,198	1,521,789	42,6	88,972	295
1999	1,420,401	159,3009	15	-37,594	1,457,995	40,9	40,554	0
2000	1,485,739	105,400	38	-57,093	1,542,832	43,2	52,921	2
2001	1,503,977	165,790	149	-151,942	1,655,920	46,4	89,453	141

Source: Ministry of Agriculture, DANE, Dian, Imports FEDEARROZ.

of consequences. First, this scarce resource is valued excessively high. Secondly, most rice producers rent the land because they lack the capital to buy it and, in turn, farmers manage land and water resources differently if they are renting the land compared to if they owned it and depended on preserving the quality of the land for future production, so the low rate of land tenure of farmers is more likely to have a negative environmental impact. Finally, the social implication of a concentration of land ownership among a restricted number of hands is a less equitable distribution of income and wealth.

3.2.4 Social conflicts

In the main irrigated rice-growing areas in Colombia some conflicts have been arising with regard to the use of water resources. Human settlements located close to water resources that are used for irrigation have resulted in this water being contaminated by organic matters such as domestic waste and garbage. This is further aggravated by the increase in waste, biological residuals and agrochemicals originating from the rice agro-industry.

3.2.5 Rice consumption patterns

Between the 1980s and 1990s, rice consumption decreased from 40 kg per capita in 1980 to 21.8 kg per capita in 1997.[27] However, over these past years rice consumption has once again increased. DANE has estimated rice consumption since 2000 based on its Household Survey, which is used to calculate the consumer price index. It was found that rice consumption was 40 kg per capita for the year 2000 and 41.5 for 2001.[28] On the Colombian Atlantic coast consumption levels were about 63 kg per capita but lower in the central zone where most of the population is concentrated, and higher in Cartagena and Montería in the North. Consumption depends on the income level, and the latter has been decreasing. Thus, the fact that rice consumption has increased suggests that there has been a general impoverishment of the Colombian people who are substituting expensive goods for nutritious goods at a relatively lower price, i.e. there is a shift towards "inferior" goods in low-income households. In the Colombian case, when the relative prices of goods such as meat, dairy products and vegetables increase, the consumption of rice, wheat and other cheap cereals also increases.

For Colombia, Peru and Brazil, the average per capita consumption is about 42 kg, which is higher than the average per capita consumption in some other Latin American countries. For example, Venezuela has a per capita rice consumption of just 15 kg, and the weighted average for Latin America is 27 kg per capita of white rice.

3.3 Environmental impacts

The Colombian Environment, Households and Territorial Development Ministry has developed a series of strategies focused on the continuous improvement of productive sectors, such as the "National Programme for a Cleaner Production", which is an environmental policy for the use and management of plaguicides, and sub-sector environmental guides.

Several factors in rice cultivation, such as agricultural extensification, an increase in the practice of monoculture, simplification of ecosystems and the use of agro-chemicals, have negative environmental impacts. Because of the importance of the rice sector as a generator of employment and for food security, it is necessary to take into account environmental conservation and the rational use of resources to ensure sustainability of the sector. Facing these challenges in rice production will require imposing the incorporation of new environmental variables for the industry to guarantee the domestic and international marketability of rice. The purpose of this is to prevent and mitigate the negative impact of intensive agriculture through the adoption of environmentally friendly technologies to maximise the sector's productivity.

[27] Fedearroz, 2001, Arroz en Colombia 1980-2001. Bogotá, Anexo 19, p.160.
[28] DANE, Encuesta Nacional de Hogares.

3.3.1 Environmental policies and normative framework

In terms of environmental concerns, Colombia already has a vast legislation that is consolidated in the National Code of the Renewable Natural Resources and of the Atmosphere, Decree-Law 2811 of 1974, through which the Colombian National Political Constitution of 1991 has established a set of public rights and duties of the State, institutions and individuals in relation to environmental matters and within the framework of the principles of sustainable development. The aforementioned National Code enacts Law 99 of 1993 through which the National Environmental System (SINA) was set up, the Environment Ministry was created, and the Public Sector in charge of the Administration and Conservation of the Environment and Renewable Natural Resources was reorganized.

The National Environmental System consists of four Research Institutes with technical and scientific support from public and private universities and research centres. It also includes 34 regional environmental authorities (Regional Autonomous Corporations, CAR) that are in charge of the protection and conservation of the environment in the different regions of the country.

The Ministry of the Environment has diffused political, limitation and environmental strategies aimed at guiding the preservation and conservation of natural resources and promoting sustainability, for example through:

- Biodiversity Policies.
- Policies for the Administration of Wild Fauna.
- Policies for the Integrated Classification and Sustainable Development of Coastal Areas.
- Forest Policies.
- Policies for Integral Administration of Solid Residuals.
- Policies and Limitations for the use and handling of plaguicides.
- Basis for population and environmental policies.
- Guides of a policy for civic participation in environmental administration.
- Policies for environmental education.
- Policies and limitations for the integrated management of water.
- Strategy for a national system of protected areas.
- Guides for the Territory Environmental Classification Policies.
- Cleaner Production Policies.
- Strategic Plan for Forest Restoration and Establishment.
- Environmental Research Policies.
- National Policies for Interior Colombian Wetland Areas.

Additionally, the country has defined a series of norms and regulations for the protection of the environment and natural resources, some of which are directly related to the rice sector:

- For hydro resources there is the National Sanitary Code (Law 09/79); for the management and handling of hydrographical basins: Decree 2857/81 and Decree 1728/02; for the use of water and liquid pouring materials: Decree 1594/84; for the efficient use and saving of water: Law 373/97; concessions for the use of public waters: Decree 1541/78; and Decree for Compensation Rates.
- With regard to the air resources, norms about atmospheric emissions have been defined in Decree 02/82, and about Prevention and Control of Atmospheric Contamination and the Air Quality Protection in Law 48/95.
- With regard to the soil resources, norms have been promulgated for the protection and classification of the territory through the municipal authorities (Law 388/97).
- With regard to ordinary and dangerous residuals there is the Sanitary Code (Law 9ª/79), Decree 2104/83 that regulates the administration of solid residuals, and Law 430/98 that dictates prohibitive norms in environmental matters with respect to dangerous wastes.
- Likewise, the National Code of Natural Resources establishes general measures for the protection and use of the fauna and wild flora; Decree 1608/78 dictates dispositions for the conservation of wild fauna and defines the adminis-

trative entities responsible for its handling, management and control; Law 84/89 instituted the National Statute for the Protection of Animals; Law 491/99 establishes the ecological insurance and reforms the Penal Code in terms of environmental crimes; Law 99/93 defines the bylaws and concessions in terms of forest use as well as the functions of evaluation, control and checking

- With regard to controls in the use and handling of plaguicides, the competent entities are the Environment Ministry, within the framework of the Law 99/93 and the Decree 1728/02; the Ministry of Health through the Law 9ª/79 and the Decree 1843/91; the Ministry of Agriculture; Resolution 3079 of November of 1995 has been promulgated through the ICA and includes dispositions regarding industry, trade, and dictates the application of bio input materials and products, fertilizers, soil correctives and related products such as chemical plaguicides, physiologic regulators.

Recently the country adopted the Andean Community of Nations Decision 436 regarding the registration and control of chemical plaguicides for agricultural use. In addition, Colombia is a signatory of the Stockholm (Persistent Organic Pollutants) and Rotterdam (Informed Prior Consent) Agreements.

3.3.2 Identification and evaluation of environmental effects

With the purpose of analysing and evaluating the possible environmental effects associated with rice cultivation, the different phases of this activity – from the development of the infrastructure to the commercialisation of the final product – were valued keeping in mind the activities in a real context, such as the use and handling of inputs and teams, waste generation, potential conflicts and benefits, natural resource use, policies and national regulations and the management abilities of producers and the community. This involved designing a matrix that incorporates the previous signal components, describing them in a subjective way according to their magnitude, frequency and intensity. The results of this evaluation are described in Table 3.10. The coloured area in the matrix means incidence. The analysis of the results are detailed in the subsequent chapters of this report, including a proposal aimed at defining measures for environmental management to improve the competitiveness and sustainability of the Colombian rice sector.

3.3.3 Identification of inputs used in rice cultivation

The rice agro-industrial chain is one of the most demanding sectors in terms of agro-chemicals for production, consisting basically of fertilizers and plaguicides of different natures, characteristics and formulations. Rice is produced in diverse types of climate, including a tropical, warm and humid climate where insects, plagues and illnesses are more prolific than in a dry climate. In addition, rice is cultivated throughout the year in areas where production is more intensive. This results in even more pest and disease attacks and increases the epidemic pressure on the cultivation in terms of incidence and severity, which in turn causes a significant increment in the costs of pest and disease control.

The information below on each of the rice cultivation activities originates from the Periodical National Rice Survey that covers all the production zones and systems, and includes different sized farms. These surveys began in 1990 and cover 180 producers per season.

3.3.3.1 Correctives

In the production of upland rice, especially in the Oriental Plains, lime applications are carried out between 5 and 30 days before sowing in doses that fluctuate between 200 and 500 Kg/ha. Table 3.11 shows the main correctives, doses and number of applications.

3.3.3.2 Fertilizers

In the Oriental Plains, 70 per cent of the technical assistants recommend the use of DAP (Ammonium Phosphate) and 60 per cent of the producers generally use it in doses higher than those recommended. DAP is generally applied in doses of

Table 3.10: Environmental effects identification matrix

PHASE			CONSTRUCTION						CROP DEVELOPMENT						POST-HARVEST								
ACTIVITY			SOIL ADEQUATION	CONSTRUCTION AND ROAD ADEQUATION	DAM CONSTRUCTION	IRRIGATION CANAL CONSTRUCTION	RESERVOIRES	BURNINGS	LAND PREPARATION	SOWING	CULTURAL LABOURS	PLAGUICIDES	FERTILIZERS	IRRIGATION	HARVEST	HARVEST RESIDUALS	WASTE MANAGEMENT	HULL AND MILL RESIDUES	RESIDUAL WATER MANAGEMENT	DRY	MILL	STORAGE	TRANSPORTATION
ENVIRONMENTAL COMPONENT	ELEMENT	INDICATOR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
PHYSICAL	LAND	QUALITY																					
		STABILITY																					
		EROSION																					
		FERTILITY																					
	WATER	QUALITY																					
		QUANTITY																					
	AIR	QUALITY																					
BIOTIC	VEGETATION	HABITATS																					
	FAUNA	LAND																					
		AQUATIC																					
	LANDSCAPE	RELATIONSHIPS IN ECOSYSTEM																					
SOCIO-ECONOMIC AND CULTURAL	COMMUNITY	EMPLOYMENT																					
	PRODUCTIÓN	AGRICULTURAL																					
		INDUSTRIAL																					
		TRADE																					

Table 3.11: Doses and number of applications of the correctives most commonly used in rice cultivation, per semester, Colombia, 2000

Corrective	Dose (Kg/Ha.)	No of Applications
Agricultural lime	100	1
Lime dolomitica	150 at 500	1
Calfos	300	1

Source: FEDEARROZ, National Rice Survey

between 50 and 300 Kg/ha in a single application; KCl (Chloride of Potassium) is used in doses of 50 to 200 Kg/ha. Depending on soil fertility, these doses may be spread over one to three applications.

Urea is used in doses of 125 to 275 Kg/ha in three applications. Ninety per cent of the assistants recommend its application and 90 per cent of the farmers use urea as a basic source of nitrogen for rice production in Colombia. In the Table 3.12 the main fertilizers are indicated they are also used in the cultivation of rice.

3.3.3.3 Plaguicides

As already mentioned, a range of products are generally used in rice cultivation, including herbicides, insecticides, fungicides, nematicides and rat-poison, which indicates the importance they have acquired within the production process and the high dependence of rice farmers in Colombia and throughout the world on these products.

Herbicides are usually applied during and after sowing. In rice cultivation, weed control begins with “burning”, which is carried out after ground

Table 3.12: Doses and number of applications of fertilizers most commonly used in rice tillage, per semester, Colombia, 2000

Trade name	Applied dose KG/HA	Number of applications
Urea	50 at 600	1 - 6
Diamonico phosphate (DAP)	25 at 300	1 - 4
Chloride of potassium (KCL)	25 at 275	1 - 4
Sulfate of ammonium (SAM)	25 at 400	1 - 4
Rafos	200 at 225	1 - 2
Triple 15 (15-15-15)	50 at 400	1 - 3
Triple 18 (18-18-18)	35 at 500	1 - 3
Triple 14 (14-14-14)	75 at 125	1
Nitromag	50 at 125	1
Agrimis	10 at 46	1
Fertiaza	10 at 50	1
Humus	70 at 600	1
Sulfgomag	125	1
Sulcamag	25 at 75	1
Vigor	20 at 46	1
Sulfurate elementary	10 at 75	1 - 3
Fertimex	20	1
Sulfate of zinc	10 at 30	1

Source: FEDEARROZ, Survey National Rice

Table 3.13: Dose and number of applications of the most commonly used herbicides in the cultivation of rice for "burnings", first semester 2000

Commercial name	Applied dose LTS/HA	Applications number
Round up	3	1 - 2
Faena	3.5	1
Glyfosan	3	1 - 3
Glyfosol	3	1 - 2
Coloso	4	1
Socar SL	3	1
Glifosato 324	3	1
Gramoxone	3	1 - 2
Goal	1.5	1 - 2

Source: FEDEARROZ, National Rice Survey.

preparation (two or three weeks), mainly to control wide and leaf weeds, graminaceae and especially red rice. Table 3.13 presents the main herbicides used in rice cultivation.

All of the farmers carry out pre-emergency weed control, especially in the irrigated rice system. In the favoured upland system, weed control is carried out by approximately 60 per cent of farmers. The third phase of weed control, identified as post-emergency, involves the use of products with certain specificity, in view of their efficiency and selectivity. Table 3.14 presents the herbicides used in the pre and post emergency phases.

Existing data allows us to determine rice farmers' preferences in terms of the use of plaguicides for weed control, as well as the consequent risks on the atmosphere, health and rice agro-ecosystems in Colombia. An aspect to keep in mind regarding its effects is that the predominant weeds have changed in terms of preponderance and aggressiveness induced by the dependence on chemicals used to control them, and in some cases these weeds have developed a resistance to the chemicals used.

Similarly, the chemicals used to control insects include a range of active ingredients of varying characteristics, both for its synthesis and action.

Table 3.14: Doses and number of applications of the pre and post emergency herbicides most commonly used in rice production, per semester, Colombia, 2000

Trade name	Applied dose LTS/KG/HA	Number of applications
Stampir	4.0	1
Classic	0.075	1
Prowl 400	3.2	1
Prowl 330	3.5	1
Nominee 100 SC	0.4	1
Command	1.2	1
Skol 60 WG	0.5	1
Facet 250 SC	1.0	1
Bolero	3.2	1
Furore 12 CE	0.8	1 - 2
Clincher	1.2	1 - 2
Foresite	2.5	1
Raft 400 you	0.7	1
Machete	3.2	1 - 2
Rifit 500	2.3	1
Rostar F.M.B. 38	2.0	1
Propanil 500	4.5	1

Source: FEDEARROZ, National Rice Survey.

Table 3.15: Doses and number of applications of the most commonly used insecticides in rice cultivation, per semester, Colombia, 2000

Trade name	Applied dose LTS/KG/HA	Number of applications
Azodrin 600	1.0	1
Basudin 600 EC	1.0	1
Bidrin 48 CMA	1.0	1
Curater 3G	1.5	1
You say	0.25	1 - 2
Dipterex 80 SP	1.0	1
Furadan 3D	0.8	1
Furadan 3G	20.0	1
Karate	0.3	1 - 2
Lorsban 4E	1.0	1 - 2
Monocrotofos 600	0.8	1
Nuvacron 60 SCW	0.75	1
Polytrin 200 EC	0.25	1
Roxion	0.5	1
Sistemin 40	1.0	1 - 2
Trichrograma *	30.0	1 - 2
Buldock	0.25	1
Trebon	0.50	1
Insectrina 200	0.30	1
Hiperkill	0.30	1
Hunter 80	0.06	1
Inisan 60 Co.Ltd.	0.70	1
Actara	0.10	1
Whip EC	0.30	1

Source: FEDEARROZ, National Rice Survey.

Application doses oscillate between one and two litres per hectare, with between one and three applications during the growing cycle. Table 3.15 shows the main insecticides used in rice cultivation. The volumes listed apply to formulations. Insecticides are applied continuously during cultivation, which means that, as for herbicides, pests are controlled artificially and non-selectively, which causes a reduction in entomo-fauna biodiversity and vertebrate populations in rice ecologies of the different rice producing regions.

The diseases that affect rice cultivation in Colombia depend on variables such as temperature, relative humidity, precipitation, since these influence the development of epidemics. Rice ecosystems are affected by a number of diseases, and these are controlled using a variety of products, as shown in Table 3.16.

3.3.4 Impacts on natural resources associated with rice cultivation

3.3.4.1 Water resources

Rice cultivation is characterized by high water consumption, irrespective of the production system. Irrigated rice requires between 8,500 and 9,000 m^3/ha of water, in terrains levelled with laser technology, while conventional land levelling requires between 15,000 to 16,000 m^3/ha of water. Most of the cultivation area in Colombia has not been laser levelled (about 1 per cent of the total rice area).

Clean water is important to the production of high quality rice. However, the continuous application of agro-chemicals can cause trace elements of these chemicals to contaminate aquifers and ground water through percolation. These effects are not well known at the moment by the scientific community, however they will increase in magnitude over time, because although ground water contamination is low at the moment, it can potentially be high if the application of agro-chemicals is not rationalised or if other alternatives are not used instead.

Given the minimal use of deep-lying ground water in irrigated systems for rice cultivation, there is currently no conflict between its availability and recovery. For the time being the magnitude of the effect is thus considered low. This may increase, but the capacity at present to mitigate negative effects is medium to high. Mitigation measures may include more rational consumption, improved knowledge on the requirements and current consumption in rice cultivation, re-cycling of used waters and better use of rainfall and superficial water.

3.3.4.2 Land resources

Land resources are affected by construction and land preparation, resulting in the soil becoming more compact and causing erosion. During the production phase, flooding, plaguicides and other factors also affect land resources.

Inadequate land preparation practices, deforestation and monocultivation cause a decrease in soil fertility and organic matter. As soil becomes more compact, its physical and chemical characteristics are altered because of the lack of permeability and infiltration, which makes it more prone to superficial erosion, nutrient wash and contamination by management practices.

The effects of inadequate land management are evident in the increase in pH and the reduction in interchangeable aluminium. Fertility can be improved by incorporating crop residuals that are rich in

Table 3.16: Most commonly used fungicides in rice cultivation, Colombia, semester 2000:1

Comercial Brand	Dose LTS/KG/HA	Number of applications
Bayleton 25 EC	0.4	1
Benlate	0.3	1
Bim 75	0.3	1
Carbendazim	0.5	1
Calidan	1.0	1
Derosal 500	0.6	1
Dithane FMB	4.0	1 - 2
Dithane M45	3.0	1
Elosal dispersion	0.8	1
Fudiolan	1.0	1
Hinosan	0.8	1
Kasumin 2%	1.25	1
Kitasin 48 CE	1.20	1
Manzate 200	0.5	1
Mertec 450 FW	0.5	1
Monceren	1.0	1
Moncut	1.30	1
Tilt 250 EC	0.50	1
Validacin 3%	1.50	1
Tifon 50 WP	1.00	1
Indar	0.50	1
Taspa 500 EC	0.40	1
Brodione SC	0.60	1
Amistar 250 SC	0.60	1

Source: FEDEARROZ, National Rice Survey.

nitrogen and potassium. Currently, the inadequate disposal of these residuals causes contamination in some zones and improper application of fertilizers increases production costs and reduces yields.

Rice-growing areas are well located but rice production activities have environmental impacts, for example the inadequate and excessive use of agro-chemicals that modify soil characteristics. To prevent this, alternative methods for pest control are advocated, such as IPM (currently in use), and reductions in dose and application frequency.

On the other hand, anaerobic conditions of flooded lands in irrigated systems alter soil characteristics. Although soil micro-organisms normally only exist in very small amounts they are essential for soil fertility and cultivation. In general, flooded soil can be recovered through management practices to achieve positive microbial activity and adequate physical and chemical conditions.

The uncontrolled burning of wastes destroys vegetative covering and alters the micro-fauna, and inappropriate disposal of organic matter from harvests and industrial processes has a negative impact on the soil. These negative impacts can be reduced by incorporating the organic waste back into the soil or through other alternative techniques, and thus improve the organic content, fertility and biodiversity of the soil.

In general, soil quality can be improved by implementing technical management activities such as biological pest control, minimum sowing and appropriate disposal of organic residuals.

3.3.4.3 Air quality

Several activities related to rice production affect air quality. The application of herbicides and fertilizers liberates harmful gases and unpleasant smells. In the milling industries, the burning of large volumes of husks releases ash and other volatile particles that are transported by the wind and leave deposits on crops, soil and surface waters. The construction of mills and other infrastructures generates solid particles that are released into the atmosphere and noise from the machinery.

Widespread deforestation to facilitate air fumigation, water distribution and drainage has resulted in a simplification of the landscape, which in turn has resulted in micro-climatic deterioration, namely reduced precipitation and longer periods of drought. Indeed, previously the drought period was during the months of January and February whereas nowadays it may extend from December to May in the most critical years. Clearly this has a negative effect on production, yields and on the sanitary levels of crops.

3.3.4.4 Biotic elements

In general, the development of the practice of monocultivation has generated a succession of alterations in the biological diversity of natural ecosystems. Although this practice is considered necessary to maintain agricultural productivity and profitability and ensure food security, the flora and fauna are affected by the various activities such as land and soil preparation, irrigation and water distribution, drainage, application of fertilizers and plaguicides, disposal of solid wastes in open fields.

Edaphically, biodiversity is especially affected by any activity that modifies the environment of living organisms, whether through flooding or the use of agro-chemicals, the effects of which can spread throughout a region, for example through the movement of contaminated water or air.

Terrestrial fauna, especially small vertebrates are affected by the application of pesticides, solid waste disposal and contamination of water resources by other residuals. In the vicinity of rice mills, the large piles of husk that have not been disposed of appropriately, contribute to infestations with rats and other undesirable species, especially in and close to urban areas. Invertebrates, especially those present in the soil, are affected by the application of insecticides and flooding. Aquatic biota is affected by activities that alter water quality, such as pesticides and fertilizers.

On the whole natural resources are affected by any activities that involve a change in land use, for example deforestation, construction works, inappropriate disposal of residues (such as dumping or burning in open fields), use of plaguicides and inappropriate disposal of their containers, and building of roads and processing mills. However, the main cause of deforestation in Colombia is not rice-related activities, but rather the growing of illegal crops, followed by corn and grasses.

3.3.5 Advances in promoting environmentally friendly production strategies

Because of the important contributions of the rice sector to Colombia's GDP, employment generation and food security, FEDEARROZ and Induarroz have been promoting environmentally friendly production strategies.

3.3.5.1 IPM

Because intensive use of agro-chemicals in rice cultivation has a significant negative impact on public health, the environment and the competitiveness of the crop, FEDEARROZ, with the support of universities and research institutes, has developed IPM for rice cultivation. These programmes are disseminated through educational programmes and printed materials. However, as yet these strategies and mechanisms have not lead to a more effective implementation and cost-effective solution.

3.3.5.2 Agreement for a cleaner production with the rice mill sub-sector

In application of a policy for cleaner domestic production, the rice mill sub-sector subscribed to an agreement with its associates and the department of Tolima regional environmental authority with the aim of improving its productive processes and reducing the generation of residuals, as well as strengthening institutional capacity for the development of more environmentally friendly technologies. Despite this, rice mills still generate approximately 400,000 tons of husks a year, and the only alternative used for handling these husks is open air burning, a process which contaminates the environment and creates conflicts with the communities settled close to these industries.

3.3.5.3 Environmental guide for the rice sub-sector

The Environment Ministry, FEDEARROZ and the Society of Colombian Farmers developed an Environmental Guide for Rice Cultivation, aimed at large, medium as well as small farmers, to provide a technical reference for sound agricultural practices and promote the continuous improvement of the sub-sector.

3.3.5.4 Competitiveness Agreement of the rice chain

The Agriculture and Rural Development Ministry, industrial companies and CEOs of rice-producing companies, with the support of different influential institutions and actors within the productive chain, have promoted this mechanism with the aim of guaranteeing sustainable economic and social development. It also seeks to ensure the sector's capacity of competing internationally through coordinated short, medium and long-term actions aimed at improving the conditions of the competitive environment of the rice production chain and firms.

3.3.5.5 Programmes for efficient use and reuse of water

Rice production in Colombia requires the development of an infrastructure of irrigation and drainage to ensure the availability and quality of water resources, taking into account environmental variables. Reality shows that, during the last decades, investment has not been focused on improving, maintaining and modernising this infrastructure to guarantee the availability of water to cultivated areas and their possible expansion. What's more, the high rate of deforestation in the basins and the development of inadequate cultivation practices have had a negative impact on water flow. Consequently the sector has defined a number of actions to protect the basins. These include a project with the Association of Users of the Chipalo River, the Ibagué Municipality, the Public Services Company of Ibagué and Cortolima to evaluate the benefits of re-using treated municipal waters of Ibagué city for the irrigation of lands cultivated with rice. Based on the results, it is hoped to replicate this pattern in other municipalities of the country.

3.3.6 Proposals for environmentally friendly rice cultivation

The rice sector plays an important role at the Colombian private level. It is therefore essential to improve the competitiveness and sustainability of the sector by implementing measures that mitigate negative environmental impacts in the short, medium and long term whilst preserving the natural resources and taking into account technical, social, environmental and economic aspects.

Hereafter we present some alternatives for sustainable environmental management within the Colombian rice sector, whilst maintaining the current cultivated area:

- Rice Sector Environmental Evaluations could be carried out as a complement to environmental evaluations (EA) of specific projects (watering and irrigation facilities, mills, agro-chemical plants, air fumigation, etc.) in the development planning programmes.
- Plan and design new irrigation facilities within environmental norms through hydro-basin conservation programmes.
- Apply environmental guides for the construction and operation of irrigation areas.
- Develop technical packages to promote IPM and Integrated Soil and Water Management to rationalize plaguicide and fertilizer use.
- Develop programmes to promote the efficient use and reuse of waters.
- Strengthen training programmes on the safe use of plaguicides and their residuals.
- Develop programmes for the recycling of cultivation and milling by-products such as crop residuals and husks.
- Optimise irrigation, drainage and the use of fertilizers.
- Develop community reforestation programmes, especially in basins where the rivers initiate.
- Optimise mechanized farming and ploughing programmes for land preparation.
- Establish plans and programmes for integrated development at the municipal level (urban and sub-urban) with a view to satisfying basic needs in terms of housing, drinking water, health, education and recreation for low-income sectors (operators).

3.3.7 Considerations for the implementation of an environmental action plan

- Formation of an Operative Committee with different institutions from the Public and Private Sector.
- Identification of each problem and possible solution alternatives.
- Definition of commitments and responsibilities.
- Definition of work methodologies at every level, either by means of campaigns or transfer programmes.
- Design of mechanisms to follow-up the Action Plan.
- Interdisciplinary Inter-Institutional Surveillance Committees must be established to study, analyse and propose the most suitable solutions to production problems to decision-makers.
- Prioritisation of short and medium term actions as well as formulation and implementation of pilot projects.
- Define an information system to maintain a permanent update of the current situation diagnosis at the cultivation level.
- Promotion of research tools, transfer and validation of alternatives that contribute to IPM in order to decrease the use of plaguicides, eliminate the use of highly toxic substances, limit the diversity of formulations and presentations of common active ingredients.

Annex: Production analysis

This annex presents the methodology used to measure the productivity of, and technical change in, agro-chemicals in the case of Colombian rice after the Green Revolution.

Productivity analysis is one of the most important aspects of agricultural economics. There are several works on the topic at the international level, but for Colombian agriculture there is a lack of documents, mainly due to the lack of long-term data series. Private entities such as FEDEARROZ have compiled entire data sets combining national cost matrices, product prices, yields, cultivated areas and other useful data to develop sector studies. In this study, rice sector productivity and technical changes are to be analysed to derive conclusions about factor substitution, productivity changes and effects of technical changes on production.

This section is divided into two sub-sections. The first introduces and formalizes the analysis of cost functions and their link with productivity. The second sub-section shows results separately for mechanized rain fed and irrigated rice, linking technical changes with productivity to generate policies aimed at reducing the use of agro-chemicals.

A.1 Production, costs and productivity: theory and background for estimation

This research uses the link between technical change, factor substitution and productivity measures to evaluate the trends of inputs and total production of Colombian rice crops for both production systems. The main hypothesis to be proved is whether, after the Green Revolution and despite the introduction of improved rice varieties, the productivity of agro-chemicals in Colombian rice production has been decreasing through time. To prove this first hypothesis it is mandatory to calculate a superlative productivity index, in principle a Törnqvist productivity index.

To support this main hypothesis other questions have to be answered. The first question is related to technical change biases for the associated technology. It would be interesting to prove if there has been any room for biases towards the intensive use of agro-chemicals in Colombian rice production. If so, it would be interesting to observe how these changes have evolved through time. An important point to analyse would be the elasticities of factor substitution, just to answer the existing relationships between inputs. All of these analyses are to be carried out in an interregional context or at least by making a comparison between both the production systems because there are implicit regional differences. In order to achieve this whole analysis it would be necessary to calculate either a production or a cost function. The Transcendental Logarithmic Cost Function approach is very useful to calculate all the mentioned measures, given the aforementioned relationship that exists between that functional form and the Törnqvist superlative index.

The reasons for using a cost function instead of a production function are clear. As mentioned by Binwanger (1974), the homogeneity of degree one is not necessary because cost functions are homogeneous in prices and a change in prices will not affect the factor ratios. Furthermore, no inversion factor coefficients matrix is necessary, avoiding overestimation of errors. Finally, there is usually little multi co-linearity among prices.

Translog cost functions allow us to handle neutral and non-neutral efficiency, and neutral and non-neutral economies of scale between years in the time series. Translog coefficients are often not biased estimates. Another important point is that shares are log-linear, thus facilitating estimation. The final reason for using a Translog function is that it allows a direct link to productivity analysis through Chambers' (1994) rate of cost diminution concept.

On the other hand, the use of other functions such as Generalized Leontieff functions would lack a clear-cut link with productivity measures despite important distinctions between long and short-term inputs despite gains in efficiency to estimate aggregated data.

A.1.1 Production and productivity issues

The use of a Törnqvist index to measure productivity and a Translog cost function would be the best option to achieve the objectives of this research. In order to introduce some definitions to approach the methods and models to be used, it is necessary to briefly introduce the theoretical framework for the whole of this study.

A continuously twice-differentiable production function has to be assumed for each rice production system, depending on factors and under the recognition that input utilization depends on time:

$$Y(t) = F(X_j(t),t); j:1,\ldots,n \quad (1)$$

where X(t) stands for an input vector containing N factors for rice production, and (t) stands for a time trend to approximate technical change.

It has to be assumed also that the function is quasi-concave in the inputs, and that it has returns to scale. Furthermore, it has to be assumed that the function is well behaved in an economic and mathematical sense. For that production function there may exist a dual cost function that depends on a vector of price factors (W(t)), production level (Y(t)), and a time trend (Chambers, 1994). That cost function stands for the minimum cost achievable by the rice producer:

$$C(W(t),Y(t),t) = \min W'(t)X(t) \quad (2)$$

This cost function is assumed to be positive, linearly homogeneous in prices of factors, concave, and increasing. No fixed costs are assumed. It is also a well-behaved function in that it is twice differentiable in arguments and continuous. This assumption is not far from reality; despite the relative cost problems mentioned above, rice producers are rational in the economic sense and they minimize costs.

It is also assumed there is a Total Productivity Factor (TFP) representing the "ratio of the output to an index of inputs" (Good *et al.*, 1997) or, more simply, which could be interpreted as the average product of *all* inputs.

$$TPF(t) = \frac{Y(t)}{M(t)} \quad (3)$$

where M stands for an input index that could be calculated using either a comparison of input expenses with total output value or geometric weights to approximate input weights. Taking logarithmic derivatives at both sides of (3):

$$TPF = Y - M \quad (4)$$

Following Chambers (1994), the expression (4) can be made operational specifying a form for the time rate of change of the aggregate input. So it is assumed that:

$$M = \sum_j S_j X_j;\ j = 1,\ldots,N \quad (5)$$

where S_j stands for the share of input *j* in the production, it is:

$$S_j = W_j X_j / C \quad (6)$$

Replacing (5) with (4):

$$TPF = Y - \sum_j S_j X_j \quad (7)$$

As was mentioned above, this kind of expression applies to continuous data, so an approximation to the Törnqvist index can be useful at this point (Good, Nadiri, Sickles, 1997):

$$\log\left[\frac{TFP_t}{TFP_{t-1}}\right]=\log\left[\frac{Y_t}{Y_{t-1}}\right]-\sum_j\frac{1}{2}(S_{j,t}+S_{j,t-1})\log\left[\frac{X_{j,t}}{X_{j,t-1}}\right] \qquad (8)$$

Following Jorgenson and Griliches (1972), productivity can de defined as:

$$FP_{i,t}=\log\left(\frac{Y_t}{Y_{t-1}}\right)-\log\left(\frac{X_{i,t}}{X_{i,t-1}}\right) \qquad (9)$$

And finally using the last two expressions it is possible to come up with a useful expression to be implemented empirically, taking into account that the sum of shares equals 1 :

$$FP_{i,t}=\log\left[\frac{TFP_t}{TFP_{t-1}}\right]+\sum_j S_{j,t}\left[\log\left(\frac{X_{j,t}}{X_{j,t-1}}\right)-\log\left(\frac{X_{i,t}}{X_{i,t-1}}\right)\right];i\neq j \qquad (10)$$

Chambers proposes his rate of cost diminution as:

$$\frac{\partial\ln C}{\partial t}=-\theta=TFP \qquad (11)$$

This expression can be approximated to enter into (10):

$$FP_{i,t}=-\theta+\sum_j S_{j,t}\left[\log\left(\frac{X_{j,t}}{X_{j,t-1}}\right)-\log\left(\frac{X_{i,t}}{X_{i,t-1}}\right)\right];i\neq j \qquad (12)$$

It is valuable to mention that the perspective found in Good *et al.* (1997) mentioned in the Theoretical Frame, will not be applied here because of sample dependency problems and because in this case it does not make economic sense. In some way irrigated and mechanized rain fed rice are independent and a panel data analysis containing both production systems is clearly not the best option. Furthermore, as mentioned above, irrigated rice accounts for 98 per cent of total production and mechanized rain fed rice for only 2 per cent, even though the latter accounts for a larger proportion of farmers.

The empirical continuous approximation of the above theory can be made using a Translog cost function since the data are easily obtainable: Shares and prices for *j* factors of production, total output (Y), a time trend (t), and a dummy variable (D) to take into account the introduction of Fedearroz-50 seed since the second semester of 1997:

$$\ln C=\beta_0+\sum_j\beta_j\ln W_j+\frac{1}{2}\sum_j\sum_i\beta_{ij}\ln W_jW_i+\beta_Y\ln Y+\frac{1}{2}\beta_{YY}\ln Y^2+\sum_j\beta_{jY}\ln W_j\ln Y$$
$$+\frac{1}{2}\beta_{tt}t^2+\beta_t t+\sum_j\beta_{jt}\ln W_j t+\gamma_d D+\gamma_{Dt}Dt+\gamma_{Dy}Dy+\sum_j\ln W_j D+\varepsilon_t \qquad (13)$$

It is usual to impose some restrictions to the functional form for it to behave well, as was expressed above. This is to ensure homogeneity of degree 1 in prices and concavity:

$$\sum_j \beta_j = 1$$
$$\sum_j \beta_{jt} = 0$$
$$\beta_Y = 0$$
$$\beta_{YY} = 0$$
$$\sum_j \ln W_j D = 0$$
$$\sum_j \beta_{jY} = 0$$
$$\sum_j \sum_i \beta_{ji} = \sum_i \sum_j \beta_{ij} = 0$$
$$\sum_j \beta_{jY} = 0$$

To avoid efficiency complications for these extended forms it is useful to use duality theorems:

$$\frac{\partial \ln C}{\partial \ln W_j} = \frac{\partial C}{\partial W_j}\frac{W_j}{C} = X_j \frac{W_j}{C} = S_j = \beta_j + \sum_{ij} \beta_{ij} \ln W_j + \beta_{jy} \ln Y + \beta_{jt} t + \beta_{jD} D \quad (15)$$

Where S_j stands for the cost share of factor *j*. Now the estimation of parameters is straightforward:

$$S_j = \beta_j + \sum_{ij} \beta_{ij} \ln W_j + \beta_{iy} \ln Y + \beta_{it} t + \beta_{iD} D + \varepsilon_t \quad (16)$$

where

$$\sum_j S_j = 1$$

Trend coefficients are used as measures for non-neutral technical change. If the coefficient appears to be positive in equation for share *j*, it can be said that technology is *j*-using or *j*-intensive. Alternatively, if the coefficient is negative, then there is a *j*-saving technical change. In this context trends appear to be especially useful. Following Lekakis (1994) it is easy to prove that the rate of cost diminution is obtained differentiating (13) with respect to time accordingly with Chambers (1994):

$$\frac{\partial \ln C}{\partial t} = \beta_t + \beta_{tt} T + \sum_j \beta_{jt} W_j + \gamma_{Dt} D \quad (17)$$

This equation is well behaved if it is concave in prices and monotonically increasing, but Chambers (1994) shows that if there are no concave inputs the conditions for cost minimization will not be affected. To prove these requirements, it is mandatory for monotonicity that "fitted shares all be positive", and for strict quasi-concavity in prices that "*n x n* matrix of substitution elasticities be negative and semi-definite" (Berndt, 1993). The equation works as a continuous estimation for Total Factor Productivity, a concept for which results depend on time since actions on land and environment are inter-temporal. This result is going to be used for empirical estimation of equation (12) above.

Equations from (16) and (17) can be estimated dropping out one of the share equations and taking the price of the dropped input as *numéraire* on the remaining share estimations. The estimation method is usually ISUR (Iterative Seemingly Unrelated Equations) as shown in Berndt (1991).

After estimating equations, it is necessary to estimate substitution elasticities to evaluate the way factors behave when substituted through time. Following Mao and Koo (1997) and Frondell (2001), partial Allen elasticities of substitution (AES), Morishima elasticities of substitution (MES), changes in factor shares caused by changes in relative prices and crossed price elasticities can be calculated. For this study, MES are estimated with their standard errors.

Frondell (1999) suggests the use of MES as a more exact measure for substitution. MES measures the percentage change in the *ratio* of input *j* to input *i* when the price of input *i* varies and all other input prices are constant. It is calculated as:

$$MES_{ji} = \frac{\partial \ln\left(\frac{X_j}{X_i}\right)}{\partial \ln W_i} = \frac{W_i C_{ji}}{C_j} - \frac{W_j C_{jj}}{C_j} = AES_{ji} - AES_{jj} = \frac{\beta_{ji} + S_j S_i}{S_j S_i} - \frac{\beta_{jj} + S_j^2 - S_j}{S_j^2} \quad (18)$$

Two inputs are: MES-substitutes if MES>0 and MES-complements if MES<0. This is an asymmetric elasticity of substitution because of its composition. MES is appropriate if technology is homothetic, and there is some evidence to show that it captures the net substitution effects if scale effects are ignored. In the case of two inputs AES and MES are equal if the production structure is CES or Cobb-Douglas. For the cases of Translog and Leontieff functional forms, MES and AES are different. Furthermore, it could happen that two inputs that are AES-complements might become MES-substitutes.

MES is the base to calculate effects of factor price changes on relative cost shares with a little transformation from Mao and Koo (1997) and Frondell (1999). Mao and Koo reference this measure as coming from Huang (1991):

$$\phi_{ji} = \frac{\partial \ln\left(\frac{W_i X_i}{W_j X_j}\right)}{\partial \ln W_i} = 1 - MES_{ji} \quad (19)$$

A relative cost share is increasing if it is less than one, alternatively if the relative cost share is greater than one it is decreasing.

Another important fact to take into account is that standard errors for AES, cross-price, and MES elasticities of substitution can be calculated asymptotically under the assumptions of constant cost shares and equality with their own estimated values (Frondell, 1999; Binswanger, 1974).

$$\text{var}(MES_{ji}) = \text{var}(\beta_{ji}) / S_i^2 + \text{var}(\beta_{ii}) / S_j^2 - 2\,\text{cov}(\beta_{ji}, \beta_{ii}) / (S_j S_i) \quad (20)$$

A.2 Empirical implementation of the model

Data were obtained mainly from FEDEARROZ and the Colombian Ministry of Agriculture. Cost shares, input prices and total production costs for one hectare of rice were obtained from FEDEARROZ cost matrices for 1981:1 to 2001:2 periods on a semi-annual basis for irrigated rice and on an annual basis for mechanized rain fed rice. All values were deflected using the Producer Price Index (June 1999=100) provided by the Ministry of Agriculture. Data on input quantities were selected as the average inputs used for production of one hectare of rice for each production system, also obtained from FEDEARROZ surveys. A trend starting 1981:1 was used to take into account technical changes over time, and a dummy variable was introduced into the cost function to control for the change of seeds starting 1997:2. Finally, production data were taken from "Arroz en Colombia, 1981-2001" (FEDEARROZ, 2001).

Five inputs were selected for the construction of the cost function and the productivity study. As is common in agricultural studies, capital (K) and labour (L) were used for econometric estimations. Capital prices were approached based on the cost of machinery used for production on one hectare during a semester. Labour prices are the cost of daily non-qualified labour for the semester for one hectare. Water quantities and prices are included in capital costs for estimations relating to irrigated rice. Estimations for this input as separate from capital were insignificant and coefficients tended to be statistically unstable. To measure agro-chemical trends, data on fertilizers (F) and other chemicals (Q) were used. Other chemicals (Q) data included herbicides, insecticides, and fungi control chemicals. Prices for fertilizers and other chemicals were used for the cost-function estimation. Measurements on the use of chemicals are based on effective active ingredients in equivalent units per semester and per hectare for both systems of production. Finally, the price of land (R) as an input was measured as the price for the rental of one hectare per semester. It is important to mention that taxes and other administrative costs were excluded from total costs in order to obtain results relating only to production activity. All prices and costs are calculated in constant thousands of pesos for 1999.

Because of different production technologies, geographical zones, harvest times, and mainly because of lack of data, the mechanized rain fed rice and irrigated rice analyses are made separately.

The estimation procedure of the cost function and the five share equations for both production systems was Iterative Seemingly Unrelated Regression (ISUR) from Eviews 4.0. To avoid estimation problems, one of the five share equations was dropped from the system, and its price was taken as *numéraire*. After this transformation, the final resulting system is cost and share equations with an error term as expressed above.

Restrictions for concavity and homogeneity imposed above are kept for the estimation. The relationships between estimated parameters allow the calculus of the entire dropped equation, mainly based on the restrictions imposed.

A.2.1 Estimation for mechanized rain fed rice

The estimation results for the case of mechanized rain fed rice input share equations are presented in Table A.1. Most commonly, the cost function is not estimated, but in this case it was important to calculate it since it is the basis for the rate of cost diminution equation that is used for the productivity analysis. Relevant results from cost equation will be exposed later in the productivity analysis. As mentioned earlier, data on prices and cost shares were taken annually from 1981 to 2001.

Due to lack of space, all tables are designed to be read in columns. For example, coefficients for the capital demand function are in the first column of Table A.1.

These results were calculated imposing the aforementioned restrictions for concavity and first-degree homogeneity in prices. The results indicate that concavity conditions are fulfilled, and that after proving the Cobb-Douglas hypothesis, the Translog cost functional form fits the data quite well. Only the dummy associated with fertilizers

Table A.1: Parameter estimates of the Translog input shares for Colombian mechanized rain fed rice 1981-2001

	Cost share of				
	K	L	F	Q	R
Constant	0.4587* (0.0205)	0.1012* (0.0133)	0.1649* (0.0120)	0.1614* (0.0198)	0.1138
Price of					
K	0.0871* (0.0109)		*(Symmetric)*		
L	-0.0293* (0.0109)	0.0233*** (0.0125)			
F	-0.0607* (0.0024)	-0.0085* (0.0028)	0.1056* (0.0013)		
Q	0.0262* (0.0075)	0.0226* (0.0051)	-0.0238* (0.0013)	-0.0111* (0.0106)	
R	-0.0233	-0.0082	-0.0126	-0.0140	0.0634
Trend	-0.0011* (0.0003)	-0.0012* (0.0002)	0.0004* (0.0002)	0.0017* (0.0004)	0.0002
Dummy	0.0049 (0.0034)	0.0011 (0.0021)	-0.0047** (0.0023)	0.0014 (0.0032)	-0.0028
Y	0.0022 (0.0093)	0.0073 (0.0064)	-0.0097* (0.0058)	0.0113 (0.0090)	-0.0111

NOTE: Standard errors in parenthesis. (*) denotes parameter statistically significant at 1% level, (**) at 5% level, and (***) at 10% level.

was statistically significant, indicating that the use of the new seed had an influence on their use, unlike the other factors.

The estimation gives some indication of capital and labour-saving technical changes for the period. The significant time trend variable of any equation means that at constant factor prices the factor shares would have changed, implying non-neutral technical change during the period. On the other hand, there are agro-chemical and land-use technical changes. This can be seen through the associated coefficients for the trend variable, which are statistically significant and positive. This shows that at least for the case of mechanized rain fed rice, more pesticides, herbicides and fungi control chemicals were being used.

Results of the substitution elasticities for the case of mechanized rain fed rice are exposed in Table A.2. All values are calculated for the second semester of 2002, but we will also discuss how elasticities evolved through time. This is to evaluate how elasticities are behaving now with a view to formulating policy measures. Elasticities for the period as a whole were also calculated.

In the case of mechanized rain fed rice, capital becomes the MES-substitute for all inputs, including fertilizers that were complements for AES and cross-price substitution elasticities. The highest substitution relationship in the case of capital appears to be with respect to chemical prices, i.e. a 1 per cent increase in the price of chemicals would lead to a 0.88 per cent change in the ratio of capital quantities with respect to chemicals. It is important to point out that the weakest MES-substitution relationship for capital is with respect to fertilizers (0.30). Labour is also a MES-substitute with respect to all other inputs. Relationships with capital (0.67), fertilizers (0.67), and chemicals (0.81) are strong. For fertilizers, there is a MES-complement relationship with land (-0.045), and fertilizers are also substitutes for all other inputs. It is important to point out that all these relationships are not so strong since all values are around zero. On the other hand, it is clear that chemicals have the strongest MES-substitution

Table A.2: Morishima elasticities of substitution for Colombian mechanized rain fed rice 1981-2001

	K	L	F	Q	R
K		0.6713 (0.1415)	0.0099 (0.0857)	1.0989 (0.047053)	-0.0393
L	0.4701 (0.1483)		0.0561 (0.1215)	1.2909 (0.0813)	-0.0762
F	0.3095 (0.0190)	0.6710 (0.0304)		0.8467 (0.0108)	-0.0864
Q	0.8871 (0.0486)	0.8173 (0.1303)	0.0695 (0.0866)		-0.0330
R	0.4354	0.6127	-0.0447	0.8209	

Note: Standard errors in parentheses.

relationship since values with respect to the prices of capital and labour are above one. For example, a 1 per cent increase in the price of labour leads to a 1.29 per cent increase in the ratio of chemicals with respect to capital. The weakest relationship for chemicals occurs with land, although the value is still relatively high (0.82). Finally, land is a complement for all other inputs but, similarly to fertilizers, there is no strong relationship with any of the inputs.

The measure of changes of relative input shares of input *j* and *i* with respect to changes in prices of factor *j*, show the following results. A change in the price of any of the inputs would increase the share of capital, though again the weakest relationship occurs with respect to fertilizer prices. Labour is similar to capital in that an increase in the price of any of the inputs increases the share of this factor, whereas in the case of fertilizers an increase in the price of land decreases the cost share of fertilizers, as might be expected. With respect to the prices of all other inputs, the share of fertilizers would increase. The case of chemicals shows that an increase in the price of capital or labour would induce a high increase in the share of that factor. Finally, the share of land decreases with increases in capital, labour and fertilizers, and increases with an increase in the price of chemicals (see Table A.3).

We now turn to the productivity analysis for each of the inputs and the total output. As can be seen in equation (12), it is necessary to estimate the rate of cost diminution (11) from the total Translog cost function. In these cases, and because of the model specification, it is possible to articulate an expression for the rate of cost diminution (17) that works out as an approximation for Total Factor Productivity (see Table A.4).

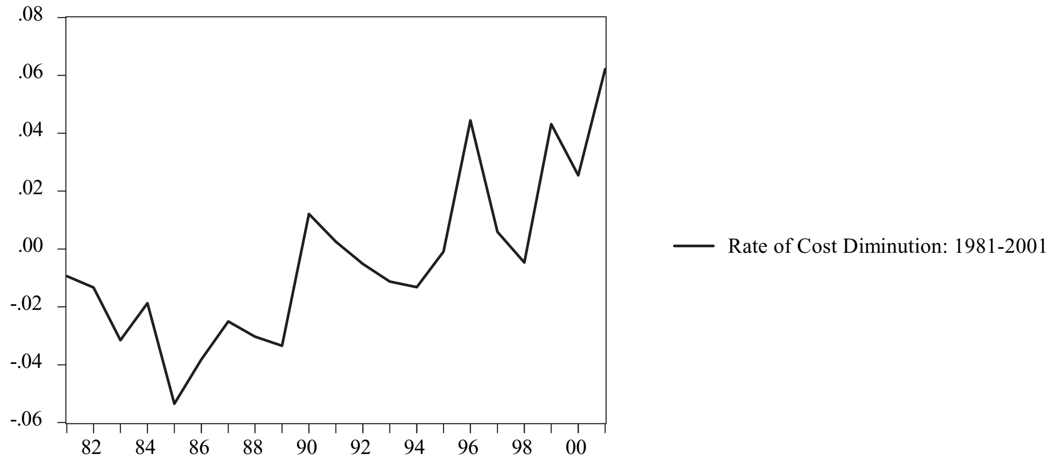
The differentiation of Cost Function for rain fed rice drops the result on equation (17). For mechanized rain fed rice from 1981 until 1990, almost all the values of the rate of cost diminution are negative and around zero, with an average of

Table A.3: Change in relative cost shares in response to a change in relative prices for Colombian mechanized rain fed rice: 1981-2001

	K	L	F	Q	R
K		0.3287	0.9901	-0.0989	1.0393
L	0.5299		0.9439	-0.2909	1.0762
F	0.6905	0.3290		0.1533	1.0864
Q	0.1129	0.1827	0.9305		0.1033
R	0.5646	0.3873	1.0447	0.1791	

Note: Data should be read in columns.

Figure A.1: Rate of cost diminution for Colombian mechanized rain fed rice: 1981-2001



0.024. From 1990 the trend is positive and on average the value of the rate of cost diminution is 0.01355 (see Figure A.1). This means that output productivity has been lowering through time. A positive value means that the cost is not lowering. Furthermore, it can be seen that in the long run the trend is on the increase.

Using the rate of cost diminution, the estimation of individual input productivity indexes is straightforward. These measures are composite indicators of efficient use for each input. It is important to point out that these indexes are very complete, because they take into account productivity changes in the whole production, and changes of each input with respect to all other inputs.

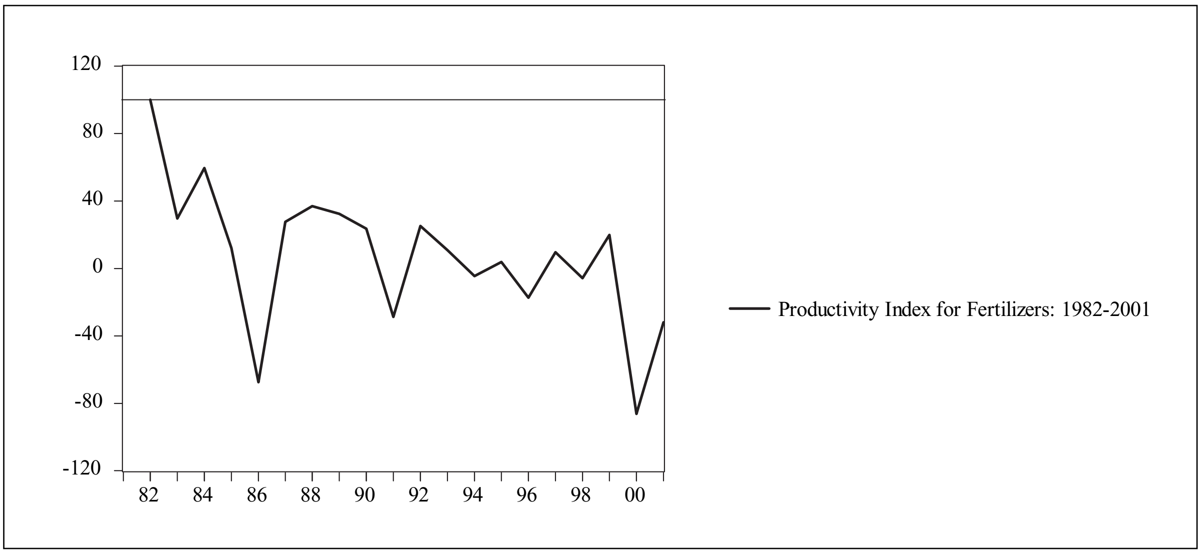
Applying equation (12) for the case of fertilizers causes the interesting results to drop. The base period for mechanized rain fed rice inputs productivity indexes estimation was 1982=100 for the first year of the sample period. The productivity index for fertilizers for the period 1982-2002 shows a constant decreasing trend. Productivity for this input never surpasses the initial level of 100. Furthermore, the index has a minimum of 86.2 for 2000, and an average of approximately 7.44 for the whole sample period (see Figure A.2). This shows that fertilizers are not productive inputs in this production system. It is important to remember at this point that the cost function showed that production is fertilizer-intensive in this case. Substi-

Table A.4: Coefficients for rate of cost diminution, 1981-2001

	Coefficient	Std. Error	t-Statistic
β_t	-0.005961	0.001314	-4.535705
β_{tt}	4.83E-05	1.37E-05	3.531172
β_{tk}	-0.001110	0.000304	-3.658769
β_{tl}	-0.001200	0.000212	-5.669723
β_{tf}	0.000406	0.000150	2.708037
β_{tq}	0.001669	0.000391	4.272302
β_{tfed}	-0.001095	0.000223	-4.923057
β_{tr}	0.00236		

Note: All coefficient results are significant at a level of 1 per cent.

Figure A.2: Productivity index for fertilizers: 1981-2001, (1982=100).



tution of these inputs for productive ones or for inputs that show a positive productivity trend is essential.

Chemicals show a similar pattern to fertilizers in that there is a downward trend in their productivity index. The trend for chemicals is similar to that for fertilizers over the initial period, but then drops more notably in the mid 1990s. On average, the productivity index for chemicals (Figure A.3) is lower than the one for fertilizers, i.e. 5.01, with a minimum of 72.02, and a maximum of 100 in 1982. Again, however, the time trend for technical change is positive since the mechanized rain fed rice system makes intensive use of this input. The conclusion is similar to that for fertilizers in that it would be best to find more productive substitute inputs to fertilizers and chemicals.

Capital should be an ideal substitute for chemicals and fertilizers, but in fact the story is similar to fertilizers and chemicals. There is a constant decreasing trend for capital as an input, which reached a minimum of -341.87 in 1999, with an average value of -38.83 for the whole period. However, the productivity index of capital seems to

Figure A.3: Productivity index for chemicals: 1981-2001, (1982=100)

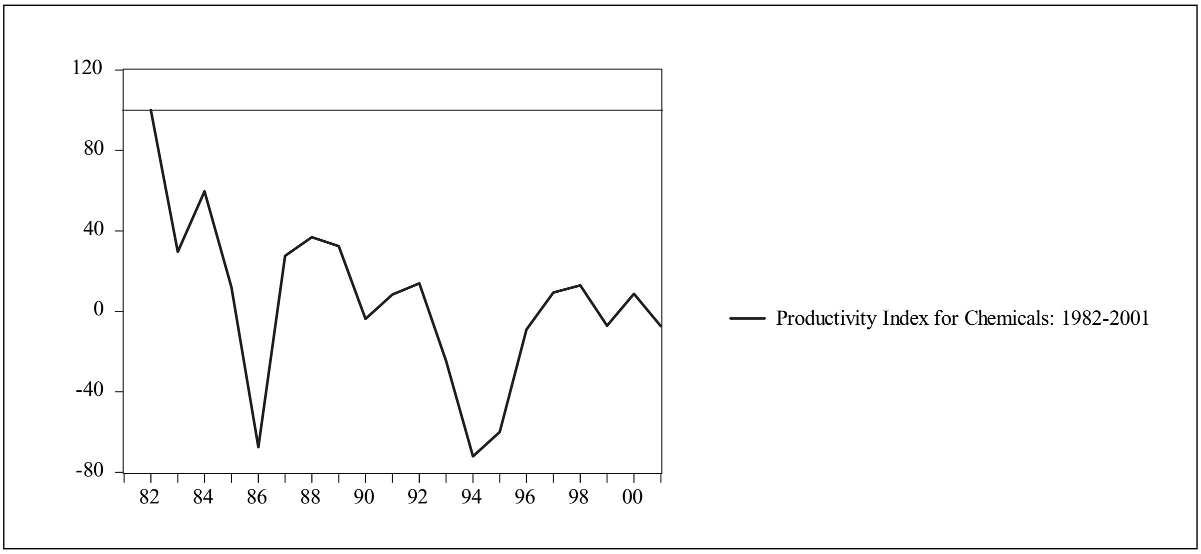
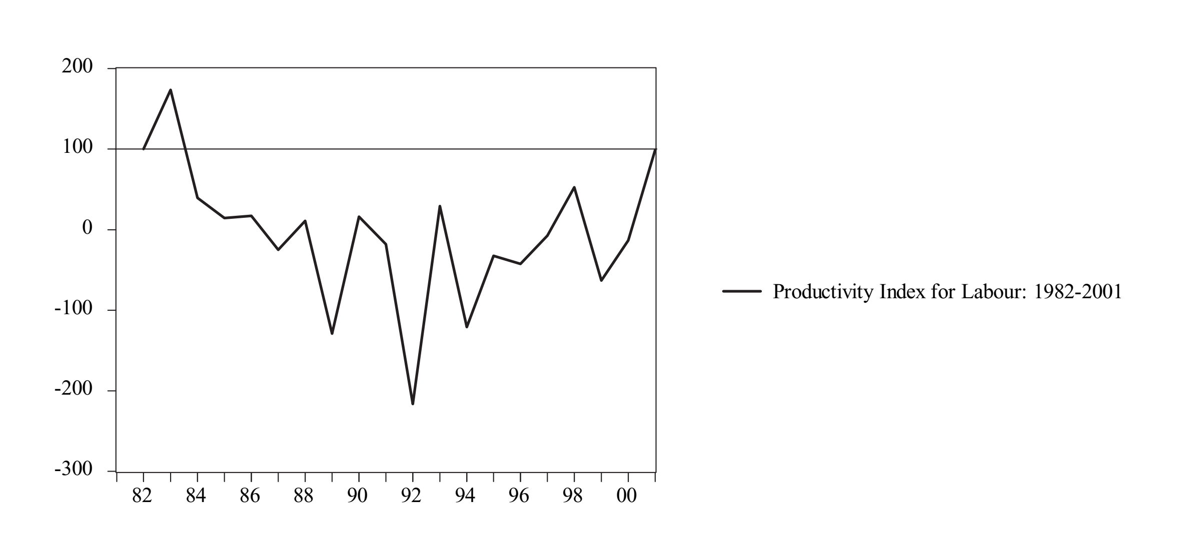


Figure A.4: Productivity index for labour, 1981-2001



be recovering in 2001. These productivity declines should be explained by the obsolescence of machinery throughout the rain fed rice zones. It is important to remember that production in this system is capital saving, which could in turn explain a portion of the productivity index trend. Capital is a substitute for all other inputs, and is strong in relationship to chemicals and fertilizers, but this is irrelevant as long as its productivity index level is low.

On the other hand, labour shows a U-shaped productivity index trend (see Figure A.4) over the analysis period. During the earlier period the productivity index is positive reaching 173.95 in 1983, after which the trend decreases with a minimum of 216 and then recovers to reach 99.11 in 2001. The productivity index of this input may continue to increase and become a productive input. There is a technical bias towards saving this input, since the trend time coefficient sign is negative. Labour

Table A.5: Parameter estimates of the Translog input shares for Colombian irrigated rice, 1981:1 to 2001:2

	Cost share of				
	K	L	F	Q	R
Constant	0.3590*	0.1039*	0.1684*	0.1879*	0.1807
	(0.0129)	(0.0079)	(0.0057)	(0.0194)	
Price of					
K	0.1425*			*(Symmetric)*	
	(0.0154)				
L	0.0023	0.0377*			
	(0.0118)	(0.0125)			
F	-0.0496*	-0.0157*	0.1176*		
	(0.0019)	(0.0020)	(0.0014)		
Q	-0.0390*	-0.0010	-0.0261*	0.1041*	
	(0.0113)	(0.0065)	(0.0010)	(0.0127)	
R	-0.0562	-0.0234	-0.0262	-0.0380	0.1303
Trend	-0.0012*	-0.0007*	-0.0001***	0.0022*	-0.0002
	(0.0002)	(0.0002)	(0.0001)	(0.0003)	
Dummy	0.0406*	0.0068	-0.0090*	-0.0269*	-0.0115
	(0.0070)	(0.0044)	(0.0023)	(0.0092)	
Y	0.0136**	0.0233*	-0.0069**	-0.0206**	-0.0094
	(0.0075)	(0.0045)	(0.0033)	(0.0113)	

Coefficients (*) denote statistical significance at 1 per cent, (**) denotes significance at 5 per cent, and (***) at 10 per cent.

Table A.6: Morishima elasticities of substitution for Colombian irrigated rice, 1981-2001

	K	L	F	Q	R
K		0.7102 (0.1457)	-0.0846 (0.1232)	0.4522 (0.088597)	0.0099
L	0.6156 (0.1239)		-0.0676 (0.1047)	0.5547 (0.0836)	-0.0151
F	0.1988 (0.0164)	0.5778 (0.0218)		0.3527 (0.0096)	-0.0416
Q	0.4334 (0.0806)	0.6995 (0.1149)	-0.0541 (0.1016)		0.0090
R	0.2386	0.5545	-0.1115	0.3197	

Note: Standard errors in parentheses.

appears to be a possible substitute for agro-chemicals in this production system because it becomes more productive through time and because MES results show substitutability for these inputs. Labour could even be a substitute for capital.

Finally, land appears as another unproductive factor for this production system and is not a substitution alternative for the other factors. Rice production under the rain fed scheme is land-intensive.

In conclusion, three unproductive inputs (fertilizers, chemicals and land) have positive and statistically significant time trends indicating that production is factor-intensive. Land appears to be the most feasible substitution factor to recover productivity under rain fed production.

A.2.2 Estimation for irrigated rice

In the case of irrigated rice, the data available covers the period from the first semester of 1981 to the second semester of 2001, on a semi-annual basis, and results are presented in Tables A.5 and A.6.

As for mechanized rain fed rice, tests were carried out on the concavity and Cobb-Douglas hypotheses. Both tests showed that the data fitted the Translog functional form quite well. All the results for dummy variables were significant at a 1 per cent level with the exception of labour. This shows that the introduction of the Fedearroz-50 seed variety influenced input behaviour. On the other hand, trends indicate that there was a bias towards the use of chemicals and less intensity for the other four factors. This fact is not consistent with the case of mechanized rain fed rice where technical changes in fertilizer and land-use occurred. Elasticities of substitution may shed some light on these differences and the way factors interact.

The MES in Table A.6 shows some interesting findings for all factor substitution patterns. Capital is a MES-substitute for all factors and, as expected, strong relationships occur with respect to labour (0.61) and chemicals (0.43). Similarly, estimations show that labour is a MES-substitute for all factors. For labour, there are strong patterns with capital

Table A.7: Change in relative cost shares in response to a change in relative prices for Colombian irrigated rice 1981-2001

	K	L	F	Q	R
K		0.2898	1.0846	0.5478	0.9901
L	0.3844		1.0676	0.4453	1.0151
F	0.8012	0.4222		0.6473	1.0416
Q	0.5666	0.3005	1.0541		0.9910
R	0.7614	0.4455	1.1115	0.6803	

Table A.8: Coefficients for rate of cost diminution, 1981:01 to 2001:02

	Coefficient	Std. Error	t-Statistic
β_t	0.000262	0.000665	0.394471
β_{tt}	2.79E-05	1.53E-05	1.825667
β_{tk}	-0.001168	0.000212	-5.518568
β_{tl}	-0.000748	0.000155	-4.831234
β_{tf}	-0.000137	7.70E-05	-1.776893
β_{tq}	0.002214	0.000292	7.580034
β_{tfed}	-0.001414	0.000556	-2.540661
β_{tr}	-0.000161		

All coefficient results are significant at a level of 1 per cent.

(0.71) and chemicals (0.69), and to some extent with respect to fertilizers and land. Surprisingly, fertilizers appear to be MES-complements for all factors, but again values are around zero except for land. It should be noted that these patterns are different to those obtained from the mechanized rain fed rice analysis that showed fertilizers to be complements for land only. Another interesting aspect lies in the fact that chemicals are a stronger MES-substitute for labour (0.55) than for capital (0.45). As is evident, all substitution relationships for chemicals are strong. Finally, land appears to be a MES-substitute for capital and land, and a complement for fertilizers. The mechanized rain fed rice case showed that land was an AES-complement for all factors (see Tables A.7 and A.8).

In the case of irrigated rice the rate of cost diminution estimation shows that all values for the period are negative. On average this measure was 0.13 with a maximum value of nearly 0.08 and a minimum of 0.19. Despite the positive trend, the standard deviation is insignificant (0.02), which shows that in absolute terms the rate of cost diminution has not changed significantly over the period. However, it is important to note that total productivity is decreasing. Figure A.5 shows this result in detail.

Figure A.5: Rate of cost diminution for Colombian irrigated rice: 1981-2001

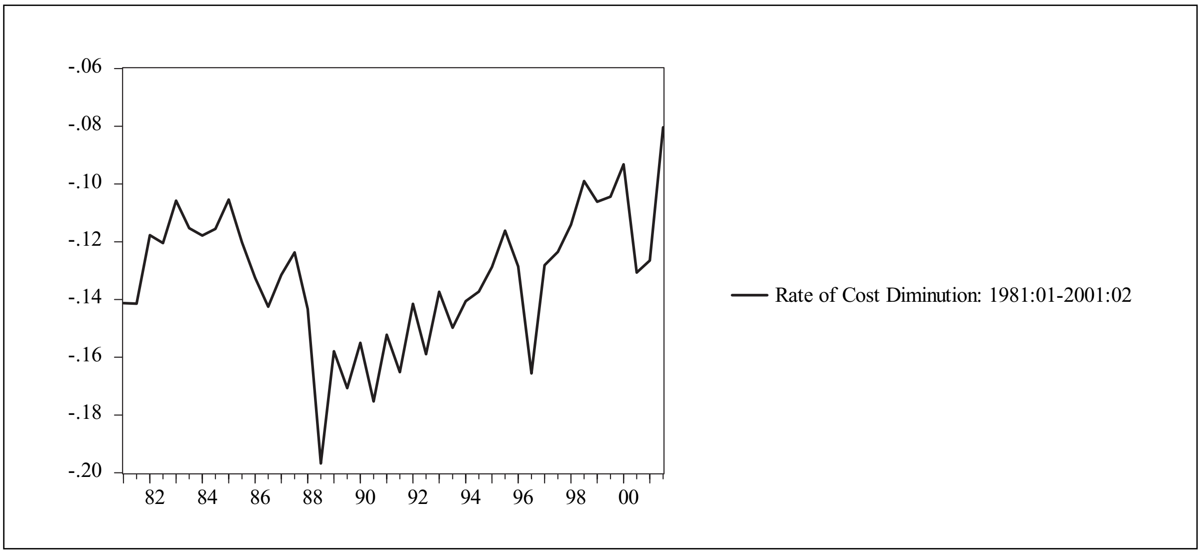
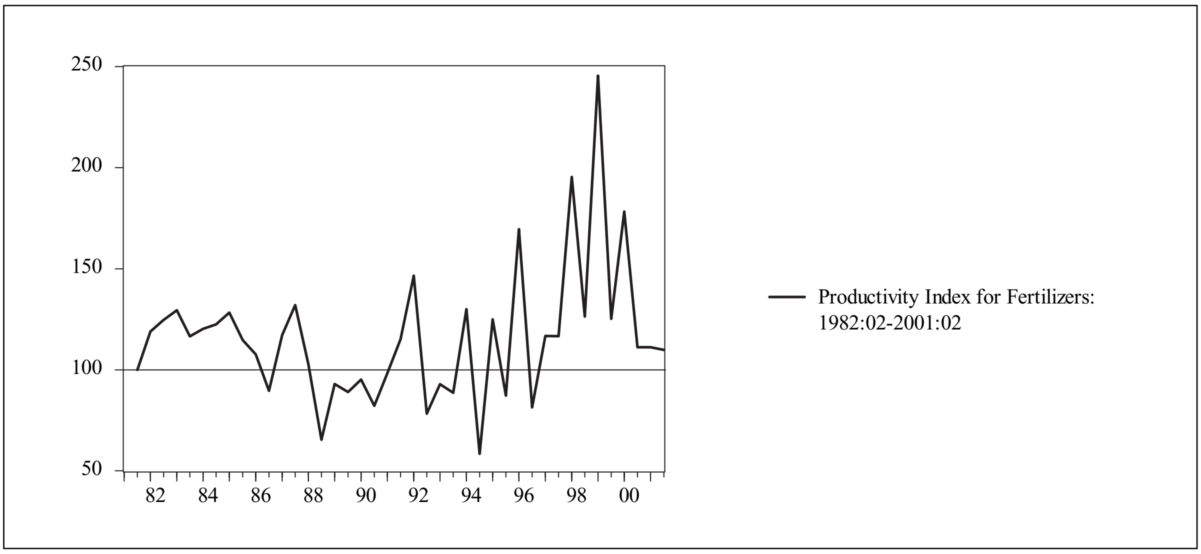


Figure A.6: Productivity index and cost share for fertilizers for Colombian irrigated rice: 1982-2001



Individual input productivity indexes show interesting results when compared to those for mechanized rain fed rice (see Figure A.6). Fertilizers show a volatile series with some indications of a positive trend starting in 1997:02 and then a downturn from 1999:02 to 2001:02, and in general, the average productivity index for this input was 116.02, which indicates it is productive. The minimum for this series is 54.85 and the maximum is 245.41. The latter doubles the productivity from the base period. It is important to remember that production under irrigated rice is fertilizer saving, contrary to the estimations for mechanized rain fed rice. However, this does not show that fertilizers are not damaging the surrounding environment.

Chemicals seem to be productive factors, just like fertilizers. Similarly to the estimations for rain fed rice, fertilizers and chemicals follow a similar pattern throughout the period. The average productivity index for chemicals was 114.7 with a minimum of 56.09 and a maximum of 239.55. Like rain fed rice, the irrigated rice production system is chemical-intensive (see Figure A.7).

Figure A.7: Productivity index and cost share for chemicals for Colombian irrigated rice: 1982-2001

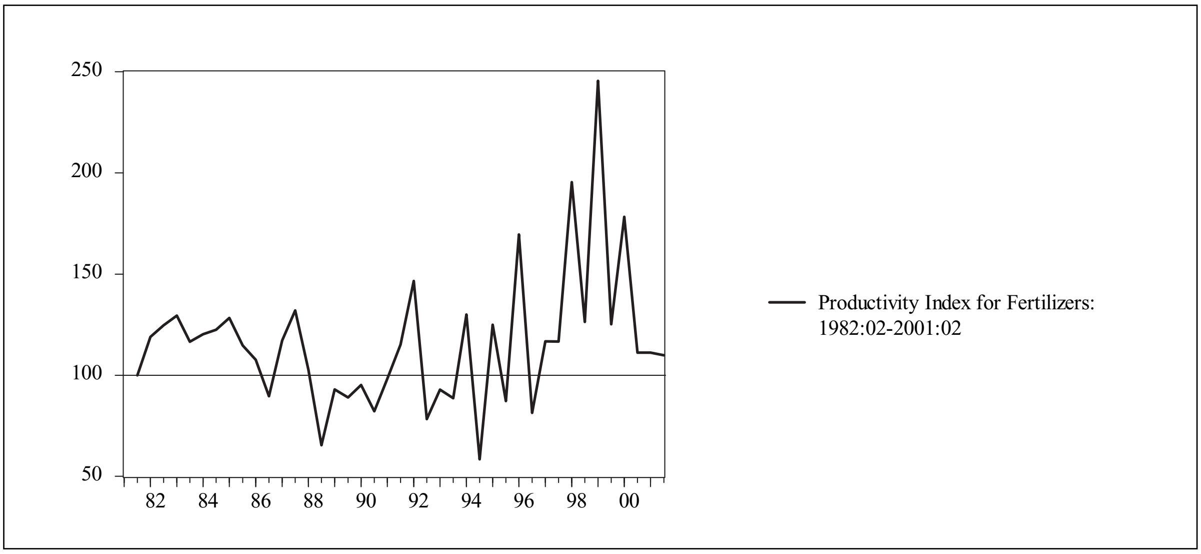
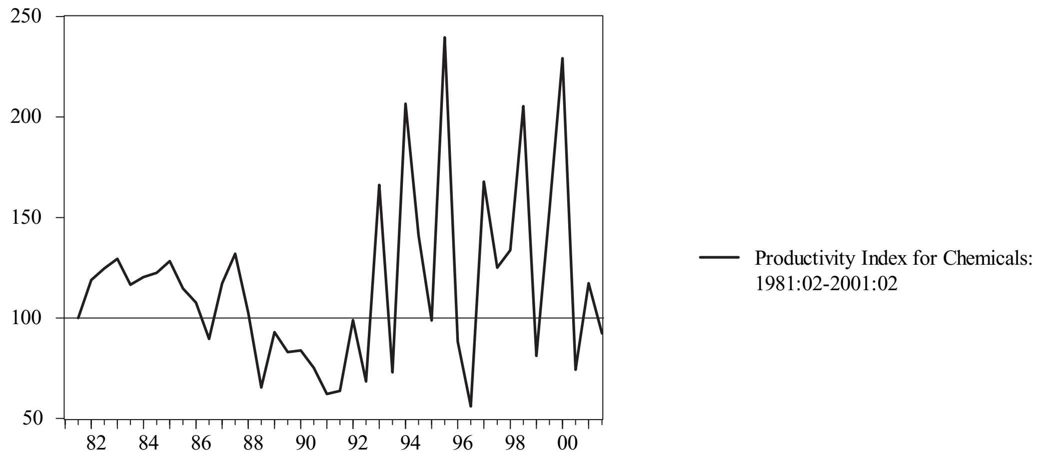


Figure A.8: Productivity index and cost share for labour for Colombian irrigated rice: 1982-2001



Not surprisingly, as a result of obsolete machinery, capital shows a U-shaped pattern along the period 1981:02-2001:02 (see Figure A.8). The productivity index starts with values around a base of 100, but then becomes unproductive from 1985:2 to reach a minimum of 71.95 in 1989:2. During the latter period, the productivity index fluctuates between 1980 and 1990, increases from 1996:2 with a small downturn in 1998:2, and finally continues with a downward trend from 2000:1 to the end of the sample. The time trend in the estimation showed that this production system is capital saving, similarly to mechanized rain fed rice.

Land appears to be the most productive input for this production system with the measure only falling below the base level of 100 for 1 year. The level fluctuates between 100 and 200, and the series appears to be very volatile. The average productivity for this input is 138.01, indicating a high productivity throughout the analysis period. Furthermore, the maximum for this series reaches 223.80, and a minimum of about 70.39. The irrigated rice production system labour saving has interesting implications in terms of environmental issues. It is now known that chemicals are being used intensively for rice production under this system, and this does not imply that those inputs are not affecting the environment. Also, high productivity may act as an incentive to use chemicals because of the excellent results in controlling pests and fungi, and since labour is a substitute for chemicals, it is the best option for reducing the use of the latter.

Finally, land appears to be the least productive input. Its productivity index shows an average of 110.30, a minimum value of 65.5, and a maximum of 161.01. The MES estimation showed that labour is a substitute for land, so it would be a great opportunity to substitute the former for the latter to stop the loss of productivity showed in the upward trend of the rate of cost diminution.

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