RICE POLICIES IN SRI LANKA: ANALYSIS OF SUPPLY RESPONSE WITH ENDOGENOUS TECHNOLOGY

by

Nihal K. Atapattu

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

DOCTOR OF PHILOSOPHY

in

Agricultural and Applied Economics

APPROVED:

David E. Kenyon, *Co-Chairman*	George W. Norton, *Co-Chairman*
Jeffrey R. Alwang	Anya M. McGuirk

Mark W. Rosegrant

June, 1996
Blacksburg, Virginia

Keywords: Rice policies, Supply response, Sri Lanka, Endogenous technology

c. 2

LD
5655
V856
1996
A837
c. 2

RICE POLICIES IN SRI LANKA: ANALYSIS OF SUPPLY RESPONSE WITH ENDOGENOUS TECHNOLOGY

by

Nihal K. Atapattu

Committee Chairmen: David E. Kenyon, George W. Norton
Department of Agricultural and Applied Economics

(ABSTRACT)

Sri Lanka achieved a high level of self-sufficiency in rice in the 1980s through a series of investments on irrigation, technological change, and marketing and trade policies. However, more than two decades of expansion in the international rice market has diminished the validity of rice self-sufficiency policies as an economic development strategy. As a consequence, trends in the international market through their impacts on reducing investments such as rice research, extension, and irrigation development have adversely affected the ability of Sri Lanka to maintain the same levels of rice self-sufficiency in the future. In the domestic policy area however, some degree of indecision exists in undertaking reforms necessary to take advantage of the trends in the international rice economy. Given the overwhelming influence rice has on the direction of national agriculture policies in Sri Lanka, it is critical to resolve this indeterminacy pertaining to rice policies.

The objectives of the present study are to estimate the producers' response to numerous policy variables that impact on the levels of rice production, and the country's ability to manage food-security under a regime of market-friendly policies. A supply response model based on the choice of technique approach with endogenous determination of technology was specified to capture the effects of policy variables on rice output determination. The dynamic effects of technology, prices, and investments on productivity are therefore accounted for in the model. The supply response system is

composed of blocks of equations for determination of investment in quasi-fixed inputs, choice of technology, and yields. Data for the period since 1974 during which notable changes took place in the rice supply situation in Sri Lanka were used in the analysis.

Results suggest that a major share of rice output growth in Sri Lanka is explained by the producers' response to government-supplied, technology-related variables such as irrigation and research. Rice supply response to input and output prices was slight relative to the response to technology variables. Model simulations showed that, under a regime of more market friendly policies, continuation of current investment trends and policies would lead to a worsening of rice self-sufficiency levels over the next 10 years. It was also observed that with modest growth in irrigation and research investments, it is possible to maintain rice self-sufficiency at levels comparable to the present.

ACKNOWLEDGMENTS

Many individuals are responsible for the successful completion of this research. Drs. David Kenyon and George Norton, co-chairmen of my graduate committee deserve a special recognition for their guidance, support, and encouragement during all stages of my doctoral program. Dr. Kenyon with his drive for excellence has contributed much to improving the quality and relevance of this work. Besides providing valuable suggestions and sharing experiences, Dr. Norton with his show of confidence kept me focussed on my work. I benefitted immensely from being around them and am grateful for providing that opportunity.

Dr. Mark Rosegrant is greatly responsible toward improving the quality and relevance of this research through his insightful comments and careful scrutiny. I am grateful to him for suggesting numerous improvements to the original model. Drs. Jeff Alwang and Anya McGuirk took it upon themselves to support and encourage me to press on when my enthusiasm faltered. They were generous with being accessible when I needed their counsel and friendship. Their support during my graduate program and particularly the latter part of my research is much appreciated and will be long remembered.

I would also like to acknowledge numerous help from other members of the faculty, particularly Drs. Daniel Taylor and Paul Driscoll. I have been fortunate to receive excellent support and friendship from the Data Lab staff, Jerry, David, Todd, and Pam.

The funding for my graduate program was provided by the Sri Lanka Department of Agriculture under SAREC Rice Project administered by IRRI. I am grateful to Dr. Nimal Ranaweera, Director, Socio-Economics and Planning Center for encouraging and supporting me to pursue advance studies.

I wish to thank our Blacksburg colleagues for having shared their life with us. Long hours spent talking about everything but economics with Bob Parsons, Jim Gray, and Gordon Groover provided some much needed diversion. It was a pleasure to have studied and struggled in the company of Line Carpentier, Remy Paczkowski, Rodney Jones, Jerry Stedge, and Murthy Khambapathy.

Blacksburg would not have been the same without our Sri Lankan friends, particularly Gamini and Deepani as well as Chrys and Badra. Thank you for having provided our kids a home away from home.

Most importantly, I would like to thank my family, beloved wife Sunetra and children Kaumudi and Chatura and recognize their contributions to this work. While completing her doctoral program Sunetra took excellent care of kids and when I was both at home and away. Their love, patience, and understanding have served as a constant source of inspiration over a period of four years.

Finally, I would like to dedicate this work to my parents in Sri Lanka, Don Mendis and Sumana Atapattu for having encouraged me to seek wisdom in reading from a very early age and supported it as best as they could.

TABLE OF CONTENTS

List of Illustrations

List of Tables

CHAPTER ONE

INTRODUCTION

Introduction

The desire to insulate domestic economies from fluctuations arising in the international rice market induced many Asian countries to adopt inward-looking agricultural policies. Because the world rice market was an unstable source of supply, these countries placed a high premium on achieving self-sufficiency in rice. In the 1970s, apprehension about imminent global food supply problems pushed agricultural policy to the center stage. Policies were designed to increase the capacity and productivity of the rice supply base and to protect producer incomes and consumers in the majority of rice producing countries in Asia. These policies have had significant success in increasing Asian rice output. From the middle of the 1970s until the late 1980s, rice production in Asia grew at a rate more than sufficient to keep up with the increasing demand arising out of growing populations and incomes. Thus, the share of imports by the countries in the South and East Asian regions declined from 60 percent of all rice imports in the world in 1970 to less than 25 percent by 1990 (IRRI, 1991). Between 1961-64 and 1983-86, among the major food grains, rice was the only commodity for which the share of imports by developing countries decreased and the share of the exports and self-sufficiency ratios remained unchanged (Tyers and Anderson, 1992). Many Asian producers have either increased rice production beyond the needs for self sufficiency or reached the threshold of self sufficiency.

From the early 1980s, distinct changes have occurred in the global food supply situation. International rice prices have experienced the most sustained decline in real terms in the post-war era, reaching their lowest levels in the late 1980s (Fig. 1-1). This downward trend was the result of several simultaneous developments. On the supply side, the advent of improved varieties and other 'green revolution' technologies have caused rice supply to grow at rates unequaled in history, while growth in demand has been slowed by sluggish economic performance and lower population growth in important rice consuming countries in South Asia. In the fast growing Asian economies, rice consumption patterns have exhibited a declining relationship with income. This surplus situation in the world market has been accentuated by the strengthening of the protectionist agricultural policies in the developed countries.

Table 1-1. Rice - International Price ($/mt), 1950-1993

Year	Current $	Constant $[1] (1990)	Year	Current $	Constant $[1] (1990)
1950	137	837	1972	137	510
1951	144	767	1973	350	1,049
1952	156	792	1974	542	1,333
1953	175	911	1975	363	803
1954	158	842	1976	255	555
1955	142	740	1977	272	541
1956	137	691	1978	368	634
1957	137	679	1979	334	509
1958	142	692	1980	434	603
1959	132	652	1981	483	668
1960	125	602	1982	293	412
1961	137	648	1983	277	398
1962	153	712	1984	252	370
1963	143	680	1985	216	315
1964	138	642	1986	211	260
1965	136	631	1987	230	259
1966	163	730	1988	301	316
1967	206	910	1989	320	338
1968	202	900	1990	287	287
1969	187	792	1991	314	308
1970	144	574	1992	268	251
1971	129	488	1993	235	221

[1] Deflated by Manufacturing Unit Value (MUV) Index for the G-5 countries.

Source: Market Outlook for Major Primary Commodities, The World Bank

Promoting self sufficiency in rice was a readily available alternative in many Asian rice economies as a domestic rice production sector was already in existence. The actual costs of such a strategy were largely hidden until recently. The dependency on policies focussed on self sufficiency has further diminished the significance of the international rice market as a reliable source of supply and restricted market development in an already thin world rice market even more. The share of rice output internationally traded has historically been the lowest of the major food grains. Over the last four decades, while world rice production increased fourfold, the share of total rice output traded declined. It is the price instability resulting from this market thinness that influenced many producers to initially overlook the world rice market in their decision making. The extent to which the price trends in the international market relate to fundamental shifts in the basic supply and demand conditions and the longer-term stability of the market remain uncertain due to the presence of aforementioned distortions in the world rice economy.

Nonetheless, current trends in the international rice market have influenced decisions that determine the long-term balance in the market. The low profitability associated with declining world price has led to a decline in investments in areas such as irrigation expansion and modernization, rice research and extension in Asian rice economies (Rosegrant, 1991; Evenson and David, 1993). The negative impact on investment has been particularly severe on programs typically supported by bilateral and multilateral donor agencies. Furthermore, there is evidence that structural reform measures implemented in the developing countries during the 1980s have severely affected the support for government infrastructure for rice research and development. Evenson and David (1993) note that the financial crises of the early 1980s impacted unfavorably upon rice research investments and that the structural adjustment programs later in the decade did not lead to a recovery of investments in rice research.

The world rice industry is characterized by a relatively few large producing countries and numerous small producers. Six of the Asian producing countries account for more than 75 percent of the global rice area and 70 percent of the output[1]. The United States, the second largest rice exporter after Thailand, accounts for less than one percent of global production. For the large number of small producing countries for whom rice is of critical importance, the changes in the global market situation raise many challenges. The urgency to reform domestic rice policies as a result of the trends in the international market is greater in smaller producing countries. Due to rising costs of improving and maintaining infrastructure (e.g., irrigation, research) and input subsidies for rice production, as well as the high opportunity cost of scarce land devoted to rice in these countries, the economic cost of producing an incremental unit of rice is fast making domestic production a poor alternative to importing rice. The limited revenue prospects

[1] China, India, Indonesia, Bangladesh, Thailand and Vietnam

due to the staple nature of the commodity may even discourage new investments and expansion as a viable economic growth strategy.

If low rice prices continue, further expanding rice production or even maintaining levels already achieved will likely compromise other critical development goals such as increasing surplus from agriculture. Alleviating income-depressing effects associated with rice production will require shifting resources to alternative products that earn higher returns. Agricultural diversification away from rice-based systems in South Asia is considered a major development alternative by leading lending agencies such as the World Bank (Barghouti, Garbus, and Umali, 1992). However, given the indeterminacy about the relevance of the international rice market as a guide for decision making, many rice deficit countries are slow to proceed with policy adjustments that jeopardize current levels of rice self sufficiency.

Growth rates in per capita rice consumption in high income countries in Asia have clearly been declining over time. In the three largest rice consuming countries - China, India, and Indonesia - per capita consumption continued to grow in the 1980s. As the economic growth in many Asian countries slowed down during the same period, the net effect of economic changes on the future demand for rice remains somewhat uncertain. However, for individual economies, the changes in demand can be predicted based on present consumption levels and expected changes in income, rate of urbanization etc. With the population in Asia expected to increase by 60 percent or more in the next 25 years, it is forecast that rice production would have to increase from 520 million tons now to 800 million tons by the year 2025 to meet the additional demand (IRRI, 1995).

From an efficiency point of view, the differences in comparative advantage in rice production caused by variations in resource endowments and changing technological innovations should determine the optimal spatial production structure for rice in the long term. In small producing countries with a dominant smallholder sector, an apparent conflict exists between maintaining a high level of rice self sufficiency and increasing farm incomes. It is widely acknowledged that high-yielding seed-fertilizer technology was scale neutral, and both large and small producers benefitted equally from it (David and Otsuka, 1990). This technology has helped create modest improvements in labor productivity. The next phase in the improvements in labor productivity, still not realized in Asian rice production, is likely to come from adoption of mechanical innovations. Under such a scenario, countries with a production structure appropriate for mechanization are likely to have an advantage. However, over 90 percent of the global rice output is produced in Asia where the average farm size is less than two hectares and the density of population is among the highest. These would influence the scope and shape of structural adjustments in the rice farm sector with important implications on future supply patterns, farm profits and prices. The scope of policy reforms in response to current market conditions will inevitably be affected by them.

Policy makers in the Asian region face a difficult choice. While low food prices are still crucial for supporting rapid transformation of these countries toward industrialization, continuation of low food-price policies cause a disproportionately large share of human and physical resources to be tied up in a low income-generating activity. The answer to this dilemma lies in finding a policy mix that assures efficient and sustainable growth in rice productivity while preserving the interests of food security.

Problem Statement

Agricultural policies concerning rice in Sri Lanka and other rice-deficient economies in Asia have reached an important juncture. Consequent to the developments resulting from over two decades of expansion in the international rice economy, agriculture policies that attempt to address countries' desires for both rice self sufficiency and faster economic growth appear to be at cross purposes. The appropriateness and the validity of rice self sufficiency as a goal in an economic development strategy is brought under question by the existing situation of the world's rice economy. However, given the heavy presence of distortions in the international rice market, major policy changes having potential to create large and sustained disruptions cannot be undertaken without consideration of the full range of impacts. For example, responses to the evolutions in the international rice market in the form of investment decline in irrigation, and in rice research and development have been severe. The long-term nature of the impact of investment changes implies the need for a thorough analysis of the full range of implications of this decline in response to a phenomenon in the rice economy that could very well be transitory.

Similar concerns about the long-term effects of changing rice policies have delayed producer countries from pursuing any serious reforms in rice policies that are likely to soften the comfortable supply cushion built up over the years. The dilemma facing the producer countries is a choice between the continuation of past policies that protect the level of food security already attained and more outward-looking policies designed to take advantage of the resource structures and production patterns.

Justification

Agricultural policies affecting the rice sector in Sri Lanka have remained archetypal of those in most other Asian rice economies. Rice is the staple food and is important politically and economically both in terms of its share of total cropped area and the work force engaged in production and processing. Consequently, a major share of investment in agriculture in the post-war period has been devoted to expanding and to improving the land allocated to rice through the construction of irrigation infrastructures. Investments directed toward strengthening of agricultural research, extension and marketing services have also been significant. The policy response of the Government of Sri Lanka to the pressures arising from the food crisis in the 1970s was typical of the rest of Asia. During the latter part of the 1970s and early 1980s, Sri Lanka undertook a massive irrigation construction scheme unprecedented in recent history. A protective environment for domestic rice production growth was created by the introduction of various price support and input subsidies and carefully managed trade. The early successes of this strategy were astounding. Sri Lanka made impressive gains in all aspects of rice production as evidenced by the growth in rice area, yield and output. By the mid 1980s, Sri Lanka appeared poised to achieve self sufficiency in rice, a long-cherished goal.

The intensity with which Sri Lanka pursued its rice self sufficiency policies was typical of most rice producing countries. However, a major contributor in this effort, the World Bank (1986), has observed " . . . Sri Lanka, where research spending, pricing policies, input subsidies, and investment in irrigation have all being geared to achieving self sufficiency in rice. Many components in the effort were appropriate, but from an economic point of view, the policies may have been pushed too far " (World Development Report, page 62). While the efforts have fallen short of realizing the goal of rice self sufficiency, Sri Lanka has not escaped the pressures originating from the trend in international price. Evidence suggests that, since the mid 1980s, the incentives for rice production has been significantly curtailed in the face of pressures arising from recent developments.

Since late 1980s, the Government of Sri Lanka has intensified reforms under its economic development strategy founded on economic liberalization and open market policies. These reforms are aimed at contraction of an over-extended public sector, liberalization of trade, and promotion of private enterprise. An economic adjustment program aimed at narrowing the fiscal gap by cutting large welfare programs, eliminating farm subsidies, and reducing non-wage, non-interest expenditures has been undertaken. In the process, several programs affecting the rice sector have been profoundly changed. The fertilizer subsidy program, of which a major beneficiary was the rice sector[2], was eliminated beginning in 1991. Subsidies for the production and distribution of seed paddy (unmilled rice) from the state farms have been severely curtailed to be replaced by a cost-recovery system and increased privatization. State participation in rice marketing through direct procurement under the Guaranteed Price Scheme by the state-owned Paddy Marketing Board has virtually ceased to exist. Major changes in the agricultural research and extension in the country have been undertaken in a move to restructure administration and streamline government services. The largest subsidy to the rice sector was provided by

[2] Fertilizer use for rice accounted for over a half of the total fertilizer subsidy expenditure.

new irrigation construction and the rehabilitation and modernization of old irrigation schemes. This subsidy has been sharply reduced.

However, the lack of firm resolve and direction in the reform of rice policies is evident in the reversals of some of these measures and the hesitancy to undertake some others. The fertilizer subsidy scheme was reinstated in 1994, although on a lesser scale. The government continues to announce procurement prices even though the structure necessary to implement them is no longer in place. State monopoly in import trade and involvement in the retail marketing of rice is still retained. On the demand side, the large subsidy on sales of imported wheat flour is maintained to benefit the urban populace. In 1994, the annual consumption of wheat flour was estimated at 720,000 tons, and the cost of the subsidy at Rs. seven billion.

The adverse impact of recent changes in the incentive structure for rice production appears to have been misjudged. Following two decades of growth, domestic rice production growth in Sri Lanka has come to a virtual halt since the mid 1980s. Recent levels of rice production have remained well below the highest rice output (1.8 million tons) in 1984/85. This lack of growth is distressing in view of the fact that since the mid 1980s a decline in rice output growth has been observed in several other countries in the region as well. The decline in output has been interpreted as showing a need for renewed research efforts. The estimated marginal rates of return to rice research reportedly exceed those for other private and public investments suggesting that there may be an under investment in rice research in developing countries (Pardey, Roseboom, and Anderson, 1991). Therefore, understanding the determinants of output growth and the pattern of rice supply response seems crucial in assessing the impacts of recent policy changes on the domestic supply situation.

In the present context, the investments in irrigation and land improvement for rice cultivation in Sri Lanka have resulted in the allocation of prime land to the production of a staple food crop with declining income-generation potential. Major portions of land newly developed for irrigated rice culture are innately suitable for production of higher-value crops such as fruits and vegetables. Increasing rice self sufficiency in a small country like Sri Lanka means higher resource costs than in large producer countries. In this sense, it is likely that Sri Lanka will find limits imposed by excessive resource costs in trying to become self sufficient. On the other hand, rice production in Asia, including Sri Lanka is influenced by the highly unstable monsoon weather since large areas are rainfed. Thus, the increase in the share of irrigated rice area adds a certain degree of stability to domestic rice production. The greater productivity of the irrigated rice fields also assures continuing commercial production under declining profitability. Thus, any new strategy for rice production would have to consider these regional differences in the production structure.

During the period 1983-92, Sri Lanka's rice output lagged population growth by nearly 2 percent. A growth of 75 percent in rice and wheat flour imports prevented a decline in per capita grain consumption. Prior to 1980, growth in rice production allowed Sri Lanka to maintain historical levels of rice consumption while maintaining a lower rate of import growth. However, in the recent past the import share of wheat flour have continued to rise. While the slow rate of income growth during the 1980s restricted changes in rice consumption patterns, the outcomes of economic modernization such as a high rate of urbanization and an increase in the proportion of working women, are likely to have affected the present consumption behavior. Better information on the long-term demand pattern for rice will be an essential component in future production policy decisions.

However, given the unacceptably high political consequences of past supply shortages and unstable prices, a policy that will likely reduce rice supply would create an extremely difficult position politically. Given the existing uncertainty about market conditions, such a strategy would only become acceptable if accompanied by dependable safeguards. Less-distortionary measures of risk bearing such as reserve stock programs might provide adequate security at an acceptable cost against short-term supply fluctuations in the market. At present, any serious attempt at policy reform over the short and medium term may have to examine measures to overcome supply problems as an integral component of the reform package.

In short, a comprehensive policy package would include consideration of (a) efficient and sustainable growth in rice productivity from a resource management and technology improvement perspective, (b) macroeconomic adjustments to remove market distortions, and (c) a mechanism for risk-bearing, taking into consideration the developments in the trade arena.

Objectives of the Study

The proposed study involves analysis of various options available to the Government of Sri Lanka for maintaining a reasonable level of food security through a combination of domestic production and use of the international market for rice (and wheat to the extent their consumption and production linkages justify it). The analysis will provide information that will contribute toward developing a viable strategy for food security in small, food-deficit economies in Asia where the staple food crop is rice. In designing a Sri Lankan case study for reaching this goal, the following specific objectives are identified:

a. to estimate the supply response for rice in Sri Lanka and the potential changes in the long-term supply situation consequent to policy shifts induced by changes in the international rice market and macroeconomic reforms,

b. to assess the impacts of policy reform measures on rice production and food supply, and
c. to assess the feasibility of managing food supply at the national level within a market-oriented policy regime.

The study should provide an assessment of the strength of each strategy available to a small rice producer in responding to the developments in the world rice market.

Hypotheses

The central theme of the research is that the rice supply growth in Sri Lanka in the post independence period largely resulted from producers' response to strategic investments and protectionist trade policies undertaken by successive governments that modified the incentive structure in favor of rice cultivation. The present state of the industry is such that it is unlikely that any new investments of a scale comparable to previous investments will occur any time soon. Understanding the pattern of producer response to economic incentives is critical in designing market-oriented policies to manage food security in Sri Lanka.

The study contains the following specific hypotheses:

1. that the responses of rice producers to government-supplied investments such as irrigation, research, and extension were more important than price incentives in increasing rice production in Sri Lanka.
2. that the levels of rice self-sufficiency in the short to medium-term will be adversely affected if the present investment trends continue.

The following hypothesis will not be statistically tested, but evidence in support or against it will be sought.

3. Sri Lanka can adopt a market dependent approach to meet its future rice needs without endangering its food security.

Methods

Objectives will be addressed by econometrically estimating the supply relationships for rice in Sri Lanka and conducting simulations to evaluate the effects of alternative investment strategies on rice production and food security.

Because of wide variation in the cost of different types of land allocated to rice in different regions of Sri Lanka, supply response has to be estimated regionally. The effects of price, irrigation, and other investment and technology development policies on supply will be examined using a dynamic supply response framework. The choice of technique approach has been used in recent studies to study dynamic impacts of technology, prices, and investments on productivity. Due to data limitations, the regional supply models will have a relatively simple structure compared with aggregated models at the country level.

The parameter estimates for demand and supply equations for rice and wheat at the national level are required for the analysis of future supply and demand patterns and import balances under alternative policies. Policy variables that government planners might use range from price policies for rice, wheat, and inputs; investments in irrigation and research; imports and exports.

With respect to the hypotheses that will not be statistically tested, the changing ability of the Sri Lankan economy to meet increasing import needs, the scale of government stock holdings required to prevent occurrence of a temporary crisis in food supply, etc. will be examined to assess the effectiveness of such measures in providing food security, enabling more outward-looking rice policies.

Plan of Study

The rest of the dissertation is organized as follows, Chapter two briefly describes the historical nature and the recent developments in the international rice market that determined the structure of policies adopted by many Asian producing countries and led to their subsequent reform. The place rice has in the economy of Sri Lanka, government policies, and recent changes in key aspects of production, consumption and policy are also discussed in Chapter two.

Chapter three examines alternative methodologies adopted to estimate supply response, and highlights the features that make the endogenous technology approach appropriate for analysis of the Sri Lankan situation. Specification and estimation of a supply response model for Sri Lanka are described in the Chapter four, and the results of the estimation and policy implications are presented are presented in Chapter five. A synthesis of the dissertation, conclusions, and recommendations are presented in Chapter six.

CHAPTER TWO

THE WORLD RICE ECONOMY AND SRI LANKA

Introduction

This chapter briefly examines the unique characteristics that distinguish the world rice market from markets for other food commodities. Most of these characteristics compelled rice producing countries to adopt policies that diminished their reliance on the market. Emphasis in this chapter is placed on recent changes in the international trade arena that suggest a greater integration of the world rice market. This examination is followed by a description of the rice industry in Sri Lanka, government policies, and an analysis of the changing political and economic role of rice. Finally, several observations and conclusions are made about what is implied by the recent adjustments in the public sector policies affecting rice.

World Rice Economy

The unique nature of the world rice market has attracted widespread research attention. The structure, conduct and performance of the rice market are well documented (Siamwalla and Haykin, 1983; Hennebery, 1985). The emphasis here is on examining the changes that have occurred in recent history.

Rice is more important to the world economy as the major staple food than is indicated by its importance among traded agricultural commodities. The global rough rice output in 1994 was 600 million tons compared to 526 million tons for wheat[2]. Over 90 percent of the world's rice output is produced and consumed in Asia. However, only 4 percent of the total rice output is traded internationally. This trade compares with over 20 percent of wheat production and 12 percent of coarse grains production. The world market for rice is described as 'thin' because of the small share of the global output that is traded, the presence of limited buyers and sellers in the market, and the unpredictable level and

[2] The term 'tons' anywhere refers to metric tons.

source of demand for the traded supplies (Slayton, 1984). Schnepf (1994), cites the absence of a major stockholder for rice, lack of consistent trading pattern, the absence of an internationally recognized marketplace, and the very low price responsiveness of demand as additional contributing factors to the thin world rice market. Further segmentation of the market according to various types of rice for which consumer preferences are quite specific adds to the volatility of the market. As a result, prices of different types of rice may move somewhat independent of one another (Henneberry, 1985; Petzel and Monke, 1980).

The thinness of the international rice market resulted in extreme short-term fluctuations in prices. Among major food commodities that are traded widely, rice has the largest volatility in both volume and prices (World Bank, 1993). The volume of rice traded internationally shows greater variability than the world production (Table 2-1). The coefficient variation of rice prices is as high as 25 percent. These extreme price fluctuations limit even further the usefulness of trade as a dependable source of supply. The natural response has been the aggressive pursuit of self sufficiency by nearly all rice-deficit countries, thus making international trade in rice even less significant.

Table 2-1 Variability in World Rice Production, Trade and Prices 1950-1989

	Coefficient of Variation [a]				
	1950-59	**1960-69**	**1970-79**	**1980-89**	**Average**
World Production	0.12	0.07	0.10	0.08	0.09
World Trade	0.18	0.09	0.12	0.08	0.12
Price - US (Constant US $)	n.a.	0.07	0.37	0.33	0.26
Price - Thailand (Constant US $)	0.11	0.15	0.40	0.35	0.25

n.a. Not available
a. The ratio of standard deviation to mean

Source: Herrman, 1993

Trends in Production

The production of rough rice from 1951 to 1993 increased from 170 to 520 million tons worldwide and from 158 to 480 million tons in Asia (Table 2-2). The structure of the rice economy is diverse with three major producers - China, India and Indonesia - accounting for two thirds of world's output. There are about 20 other countries, a majority of them in Asia, that produce more than one million tons of rough rice annually.

World production of rice increased significantly over the last 4 decades. The source of growth initially was an expansion of land area under cultivation. By the 1970s this expansion had nearly ended in most countries. The area harvested increased from 103 to 147 million hectares between 1951 and 1993 and peaked at 150 million hectares in 1989 (Table 2-2). Over 90 percent of this area was located in Asia. The growth in rice yields since mid 1960s has been unprecedented following the spread of green revolution technology. Since then, over 90 percent of the growth in production is estimated to have been contributed by growth in yield. The growth in production slowed down during the 1980s compared to the rates observed during the 1970s. The slow down in production growth over the two periods is explained by a decrease in the yield growth rates.

Table 2-2 World: Rice Area Harvested and Rough Rice Production by Geographical Region, 1951-1993

YEAR	Area World ('000 ha)	Area Asia ('000 ha)	Production World ('000 tons)	Production Asia ('000 tons)
1951	103725	96855	170532	158520
1955	110868	103038	209786	195022
1960	118483	110106	218874	202021
1961	115501	106958	215678	198802
1962	119582	110388	226535	207391
1963	120277	110827	246970	227393
1964	125218	114951	262769	241918
1965	124985	114257	254126	232218
1966	125843	115489	261043	240078
1967	127713	116693	277565	253690
1968	129450	117940	288829	264094
1969	131374	119681	295398	270553
1970	133128	120949	316439	290156
1971	134808	122774	317877	292286
1972	132581	120857	307998	282422
1973	136866	124387	335465	308077
1974	137235	124431	332770	303566
1975	142128	128156	358096	325891
1976	142159	127106	348648	316077
1977	143994	129404	370509	338757
1978	143786	129273	386531	354488
1979	141570	126916	376625	342944
1980	145008	129331	398881	362104
1981	145796	129844	411791	374311
1982	142220	126328	424840	386328
1983	143534	129392	450768	417802
1984	145247	130270	467878	430520
1985	144412	130032	471056	432963
1986	145288	130157	471270	432261
1987	142240	126508	464056	424420
1988	147083	130940	490846	447514
1989	150139	133334	517443	472551
1990	147995	133014	520581	480123
1991	147816	132240	517410	474130
1992	148424	131852	527913	481935
1993	147517	131665	527413	482549

Source: World Rice Statistics, IRRI

The decline in the rate of growth of output, particularly since the mid 1980s has renewed concerns about the future rice supply in Asia. The decline in the growth rates and the factors contributing to them vary from situation to situation. Production gains due to higher productivity were exhausted first in the East Asian countries which adopted new high-yielding technology well ahead of those in South Asia. The slowdown in productivity growth in individual countries was effected to varying degrees by the physical limitations experienced under highly intensified rice cultivation. Lowering of production intensity in response to declining profitability in rice farming also contributed to the production decline. This decline in profits resulted mostly from domestic policy adjustments driven by the decline of rice prices in the world market.

Trends in Consumption

While rice is consumed widely around the world, its importance as a staple is nowhere as predominant as in Asia. Net exports of milled rice from Asia amount to less than 5 million tons, and the balance is consumed in the region. The average consumption levels vary widely across individual countries starting with per capita consumption rates of around 150 kg per year in countries like Indonesia, Bangladesh and Thailand (Schnepf, 1994).

The growth rate of rice consumption has slowed down in Asia in the recent past. This slow down has been the result of several concurrent developments. The population growth rates have slowed in the heavily-populated South and Southeast Asian countries. The low rate of economic growth in the highly-populated low-income countries in South Asia and the decline in per capita rice consumption in the high-income East Asian countries has resulted in an overall decline in per capita consumption trends.

The per capita rice consumption levels in many Asian countries have altered significantly over time. The large sectors of population in northern China, India and in Pakistan whose staple food is wheat obscure actual trends in rice consumption in these countries. In Asia, recent evidence indicates that the growth rate of wheat consumption has been higher than rice. Per capita rice consumption clearly declined in countries that had very high incomes. In Japan, rice consumption stabilized below 100 kg per capita. In countries with low incomes, rice consumption levels did not fall except when the initial levels were well above average. It is clear that rice consumption exhibits properties of an inferior good at very high incomes. But the evidence from Asia also suggests that, even at low per capita incomes, rice consumption can be adversely affected by urbanization or changes in other demographic characteristics. Ito, Peterson, and Grant (1989) reported negative income elasticities for rice for most Asian economies and claimed that it is becoming an inferior good in Asia. Subsequent studies disputed this claim and showed that negative income elasticities are not as widespread and are affected by many other factors (Huang and David, 1991). The demand behavior for rice is examined in detail later.

International Trade

The percent of rice output traded has remained virtually unchanged over the last 4 decades despite significant growth in output (Table 2-3). Exports of milled rice increased from 4.1 to 16.1 million tons over the period 1950-1993 but exports as a share of use remained stationary at 4 percent. Nonetheless, significant shifts have occurred in the direction of trade.

The predominant position of Asia as a source of rice exports as well as a destination for imports changed dramatically over the last four decades. Asia's share in rice exports dropped from over 90 percent before 1950 to less than 55 percent by 1990. Over the same period, the import share dropped from 60 percent to less than 25 percent (IRRI, 1991).

The peculiar structure of the international rice market is evidenced by the fact that the two largest exporters -Thailand and USA- which jointly account for more than 60 percent of the export market share, produce less than 6 percent of the global output. The dominance

Table 2-3 World: Milled Rice Production, Consumption, Exports, and Exports as Share of Use

YEAR	World Production '000 tons	Total Use '000 tons	Exports '000 tons	Exports as a Share of Use %
1961	147.3	149.2	6.3	4
1962	155.1	151.2	7.3	5
1963	169.0	165.2	7.7	5
1964	180.7	179.7	8.2	5
1965	172.9	172.2	7.9	5
1966	179.0	178.5	7.8	4
1967	188.9	186.1	7.2	4
1968	194.9	191.6	7.5	4
1969	201.1	199.2	8.2	4
1970	213.0	210.6	8.6	4
1971	215.8	216.5	8.7	4
1972	208.9	213.2	8.4	4
1973	227.6	222.6	7.7	3
1974	225.7	226.5	7.3	3
1975	243.1	232.3	8.4	3
1976	235.8	236.8	10.6	4
1977	250.6	244.2	9.6	4
1978	262.4	252.5	11.9	5
1979	256.8	258.2	12.5	5
1980	267.8	273.1	12.0	5
1981	277.4	282.4	10.8	4
1982	283.6	283.5	11.0	4
1983	305.3	300.6	11.5	4
1984	315.9	308.3	10.7	4
1985	317.5	318.6	11.7	4
1986	317.2	320.7	12.8	4
1987	313.5	319.6	11.2	4
1988	329.7	325.4	13.9	4
1989	343.1	338.2	11.7	4
1990	350.7	345.9	12.1	4
1991	349.5	351.5	14.1	4
1992	352.6	355.1	14.8	4
1993	352.2	356.9	16.1	5

Source: Schnepf, R.D., and B. Just, 1995.

of the export market by these 2 countries occurred within the last four decades as traditional exporters were experiencing production problems. However, as the political constraints that virtually excluded traditional exporters such as Myanmar, Vietnam and China from the export scene changed, larger surpluses have become available for export from these countries.

Demand for Rice in Asia

The long-term demand pattern for rice and the prospects for long-term demand growth in Asia have been intensely debated. The growth rate of total rice consumption in Asia as a whole has declined over time. However, the total and per capita consumption levels of rice declined in some countries, increased in others and remained stable in a few. Several studies have forecast a rapid weakening in demand, making rice exhibit properties of an inferior commodity in the context of its demand in Asia. Other studies have identified various developments that contributed to a weakening of rice demand, but have predicted only modest negative effects. A stylized fact of economic development has been that, with the increase in disposable income, animal and dairy products are substituted for starchy staples in the diet. The evolution of food consumption habits in developed Asian economies such as Japan and Taiwan have exhibited similar behavior despite strong cultural ties to rice. Thus, the debate on rice demand is actually concerned with the timing and the strength of this phenomena in the Asian context rather than an individual country level.

Ito, Peterson and Grant (1989) claimed that most Asian countries have already entered a stage that displays a declined importance of rice in the diet, evidenced by either negative or very low income elasticities of demand. Their study of rice consumption patterns in 14 Asian countries over the period 1961-1985 showed secularly declining and even negative income elasticities for most, including low income countries. Previously, negative income elasticities for demand for rice had been reported only rarely: e.g. for Japan (FAO, 1971), rural areas in South Vietnam (Daly et al., 1981), South Korea (KREI, 1984), and Thailand (Mann, 1982). Ito, Peterson, and Grant also cited several individual studies that suggested a pattern of declining income elasticities for rice over time in several Asian economies.

The results of the study by Ito and others have been disputed on methodological grounds by Huang, David and Duff (1991). Their estimations showed that income elasticity estimates obtained by Ito and others could be substantially understated. Several Asian economies for which negative income elasticities were reported by Ito and others have per capita income levels that are not sufficiently high to induce a decline in cereal consumption. In another critique, Bouis (1991) argued that the decline in per capita consumption can be explained by increased commercialization of rice farming and growing urbanization, not by rising incomes alone.

Ingco (1991), using time series data, estimated a demand system for major food commodities in the Philippines. The analysis revealed that rice is still a normal good in the Philippines. However, the income elasticity of demand appeared to have declined slightly over time. Income elasticities were positive for wheat and negative for corn which is an important part of the staple diet in some parts. Bouis's (1989) analysis of the pattern of food demand in the Philippines based on household food expenditure survey data revealed that the income elasticities for rice were negative (-0.20) in the urban areas and positive (0.02) in the rural areas. The income elasticities of demand for wheat (and other cereals excluding corn) were positive for both areas with the rural areas having a value almost twice as large as that in the urban areas.

Huang and David (1991) attributed the changes in rice consumption patterns in Asia to structural change as measured by the rate of urbanization, which was identified to have negative effects on the consumption of rice and course grains and positive effects on wheat. This is plausible as rice lacks the convenience that wheat has for urban consumers. Their study of rice consumption changes in 11 countries over the period 1970-1990 showed that only Japan and Thailand have negative income elasticities of demand for total cereal grains (Table 2-4). It is evident from their results that urbanization has led to a slow down in rice demand growth in a majority of Asian economies.

A comparison of results obtained in the various studies shows that the estimates of income elasticities of demand obtained from time series studies are generally lower than those based on cross sectional data. Huang and David (1991) argue that when urbanization and interdependence of rice and all other commodities are incorporated by estimating complete demand systems, estimates of income elasticities based on time series and cross-sectional analysis become remarkably consistent. In such a situation, rice becomes an inferior good only in a few economies like Japan where either the per capita incomes are very high or Thailand, where the initial levels of rice consumption were extremely high.

Analysis of changes in food demand patterns and econometric evidence indicate that rice is substituted at the low-end of the spectrum for coarse grains such as corn, barley, and millet. With further increases in income, particularly accompanied by events such as urbanization which induces changes in life style, wheat becomes a high-end substitute to rice.[3] It is evident that a change in the unique position historically occupied by rice in the

---

[3] Similar transformation of food consumption habits is reported for countries in Africa.

Table 2-4 **Estimated Price, Income and Urbanization Elasticities for Cereal Demand in Asia**

Country	Commodity	Mean Budget Share	Elasticities: Own Price	Expenditure	Urbanization [b]
Bangladesh	Rice	0.95	-0.92	0.38	-0.15
	Wheat	0.05	-2.48	1.82	2.95
China	Rice	0.46	-0.35	0.43	0.19[a]
	Wheat	0.33	-0.58	0.49	1.08[a]
	C. Gr.	0.21	0.04	0.25	-2.09[a]
India	Rice	0.55	-0.52	0.53	-0.24
	Wheat	0.25	-0.16	0.20	1.56
	C. Gr.	0.20	-0.26	0.53	-1.24
Indonesia	Rice	0.86	-0.88	0.47	-0.09
	Wheat	0.05	-0.83	0.24	4.54
	C. Gr.	0.09	-0.71	0.94	-1.30
Japan	Rice	0.78	-0.94	-0.21	-0.34
	Wheat	0.18	-0.06	-0.01	1.83
	C. Gr.	0.04	-0.25	-0.20	-1.40
S.Korea	Rice	0.75	-0.81	0.46	0.11
	Wheat	0.10	-0.55	0.90	0.27
	C. Gr.	0.15	-0.50	0.43	-0.72
Pakistan	Wheat	0.65	-0.31	0.14	0.29
	Rice	0.24	-0.40	0.49	-0.11
	C. Gr.	0.11	0.18	0.19	-1.45
Philippines	Rice	0.69	-0.96	0.25	-0.46[a]
	Wheat	0.14	-0.35	0.06	2.32[a]
	C. Gr.	0.17	-0.24	0.10	-0.05[a]
Thailand	Rice	0.95	-1.07	-0.14	-0.04
	Wheat	0.04	-0.27	-0.12	1.22
	C. Gr.	0.01	-0.15	0.28	-2.96

Source: Adopted from Huang & David, (1991), Table 7.

a. Elasticities derived from parameters that are statistically insignificant.

b. Urbanization elasticity is defined as percent change in consumption as a ratio of one percent change in urban population

Asian diet has been facilitated by the availability of a broader range of alternatives and the closer integration of global food markets.

Even though the per capita incomes in several Asian countries have undergone rapid increases in the recent past and urbanization has increased, the strength of the combined effect of the two factors still appears to fall short of producing a decline in the total rice demand in the region. The additional demand growth induced by still high rates of population growth as well as income growth in large sectors of low-income population are likely to outweigh the impact of forces that reduce rice consumption.

The aggregate impact of factors that affect the level of rice demand was examined in an inter-country study that estimated the rice consumption needs of the five major rice consuming countries in the Asia (FAO, 1991)[4]. It was observed that, over the period 1976-78 to 1984-86, the aggregate consumption of rice grew in all five countries at rates between 39 percent (Indonesia) and 21 percent (Bangladesh). The per capita consumption of rice increased (between 22-27 percent) in all countries except Bangladesh. During the same period per capita private consumption expenditures grew in all countries at rates between 5 percent (Philippines) and 62 percent (China). FAO projections indicate that, even after making allowances for a decline in the rate of growth

---

[4] China, India, Indonesia, Bangladesh and the Philippines.

of demand due to income growth and urbanization, aggregate rice consumption in the year 2000 will be between 39-65 percent above 1984-86 level. In most economies, the decline in the rates of growth in demand for rice induced by income growth and expansion of urbanization is surpassed by the additional demand created by population growth. Recent estimates by IRRI indicate that to meet the demand created by increasing population in Asia, the supply of rice has to increase to 800 million tons by year 2025.

Changing Public Sector Role in Rice

Policies influencing the rice sector in Asia include an elaborate set of price, trade and investment policies. The particular mix of policies adopted by an individual country depends on the balance sought between two conflicting objectives of maintaining low and stable prices for consumers particularly in the fast growing and politically influential urban sector, and protecting the livelihood of large numbers of traditional rice farmers. Given the highly unstable nature of the world rice market, advancing these objectives moved most countries toward adopting rice self-sufficiency as the primary policy focus. Thus the individual elements of the package: public investment policies (infrastructure facilities such as irrigation development, research and extension, and market facilities), credit policies, price and trade policies were all focussed on this single goal. In more affluent East-Asian countries many of the same policies were implemented, but with the primary goal of protecting producer incomes.

The improved supply situation in the world rice economy and the waves of economic liberalization and market-orientated reforms sweeping through a majority of the economies, have brought about profound changes in the range and scope of rice policies retained by these countries. The changing scenario is examined below with respect to major categories of policies.

Investment Policies

Prior to the development of new high yielding technology, irrigation expansion was the single most important source of production growth in the Asian rice economy. Irrigation expansion started early in the 19th century in countries such as Japan and China and intensified in the rest of Asia mostly after World War II. Between 1960 and 1980, the total irrigated rice area in Asia grew at a rate above 2 percent per year (David and Rosegrant, 1991). However, the rate of irrigation expansion has dropped well below one percent since 1980.

International lending by bilateral and multilateral donors was a major catalyst in the growth of irrigation in Asia. Such investments were prompted by the scare of large-scale food shortages and starvation in heavily-populated Asian countries, and were encouraged by the high profitability of such investments subsequent to the green revolution technology. The current trends in irrigation investments are explained by declining profitability of irrigation investments resulting from the declining food prices, and the increasing cost of development due to a decrease in the share of unexploited irrigation development potential (David and Rosegrant, 1991). Increased complacency associated with the long period of relatively favorable food security in Asia has facilitated this quick shift in priorities.

Rice Research & Extension

The potential of rice research and extension in achieving the food security goals were realized with the major improvements in the rice productivity potential achieved following the development of high yielding technology at research institutions led by the International Rice Research Institute (IRRI) and the national agricultural research systems (NARS). The new high yielding rice varieties particularly well suited to irrigation environments significantly improved the profitability of irrigation investment and the productivity of research and extension systems. However, recent investments in agricultural research and extension all have followed the declining trend observed in irrigation. This decline seems to have been induced by decreased profitability associated with rice farming, a comfortable global rice supply situation, and efforts to streamline the public sector (Evenson and David, 1993).

Trade and Pricing Policies

Trade in rice is heavily regulated with various government agencies directly engaged in both domestic and international marketing of rice. Maintaining the delicate balance between guaranteeing domestic supply at an affordable price and protecting producer prices often has required state intervention. Until the early to mid 1980s, rice exports from traditional exporters such as Thailand and Pakistan were taxed. In rice deficit countries, imports were often carried out directly by government agencies. When permitted, imports by private dealers were directly regulated by state agencies through licensing and quota arrangements. Partly in response to the secular decline in world prices, rice export taxes have been abolished or sharply reduced in recent years. However, many controls still continue in the importing countries.

Domestic rice pricing policies in many Asian economies have not escaped the pressures arising from trends in the global economy. Historically most importing countries instituted policies to protect domestic rice producers. As estimated by the Nominal Protection Rates (NPR), in most Asian countries, producers received some degree of protection in the past (Huang and David, 1991). Over time, protection rates increased and remained very high in the rapidly-growing economies such as Japan and South Korea, while in the majority of developing countries, they mostly remained positive but low. Policies relating to input pricing indicate that where a domestic fertilizer manufacturing sector was present, the protection given to domestic industry imposed a tax on domestic rice producers (Krueger, 1991). It is suggested that the combined effects of policies affecting rice production has been unfavorable to producers except in Japan, South Korea, and perhaps Indonesia (David and Rosegrant, 1991).

The impact of general macroeconomic policies on the incentive structure for agricultural production was not well understood until recently. It has been observed that the overvaluation of the domestic currency caused by industrial protection and exchange rate misalignment have more than offset the direct incentives accorded to agriculture (Krueger Schiff, and Valdes, 1991). The agricultural policies adopted by individual economies in Asia have not been homogeneous. Yet after adjusting for indirect taxation caused by currency overvaluation all the Asian countries studied were found to impose a net tax on their rice producers.

Rice Economy in Sri Lanka

Agriculture provides the primary source of surplus for economic development in Sri Lanka. Despite significant expansion in industrial and manufacturing output over the last two decades, agriculture still remains the dominant sector of the economy. In 1991, it contributed 23 percent to GDP and 31 percent total export earnings (Central Bank of Sri Lanka, 1991), and employed nearly a half of the population (Department of Census and

Statistics, 1994). The structure of the agricultural sector has changed little over the years. The export-oriented plantation sector produces tea, rubber and coconut, and the subsistence sector produces rice and food crops mainly for domestic consumption.

Around 29 percent (1.9 million hectares) of the total land area in Sri Lanka is cultivated. The 3 main plantation crops i.e. tea, rubber and coconut, cover around 40 percent of the cultivated area, and a slightly larger area is allocated to rice. Rice covers approximately 900,000 hectares, the largest area under any single crop in Sri Lanka. It provides basic livelihood to more than 700,000 farm families. During the last 3 decades, rice production as well as its contribution to the national economy has been continuously growing. Presently rice accounts for more than 25 percent of the agriculture component of the GDP (Central Bank of Sri Lanka, 1993).

Political Economy of Rice Policies

Being an island nation, food self sufficiency founded on rice cultivation has historically been undertaken out of sheer necessity. After independence was granted in 1948, working to regain rice self sufficiency became a readily accepted policy focus. Due to the large share of population involved in rice cultivation, rice was an excellent choice as a means of achieving distributional objectives. After more than a century of neglect under colonial rule, investments in rice were needed and could be easily justified. As a nation striving to find its place among a large number of newly independent colonies, appealing to historical roots of food self sufficiency was a way of instilling national pride. The colonial policy of developing plantation agriculture at the expense of domestic food production had functioned reasonably well during the occupation period due to the availability of cheap rice supplies from other colonies in the British empire such as Myanmar (formerly Burma). The vulnerability of such a policy had become evident during World War II when the rice supply situation was threatened which resulted in food shortages. This required rationing and price controls for rice for the first time.

The rice ration scheme was inherited by the state after independence and remained a key element of national politics for 30 years. While the state maintained a favorable attitude towards domestic rice producers, the limits to implementing producer-friendly policies without alienating politically powerful urban consumers became evident when food riots occurred in 1953 following proposals to increase the price of the rationed rice. Therefore, successive governments of Sri Lanka attempted the delicate balance of producer incentives and consumer protection. The rice subsidy scheme, under which a certain minimum quantity of rice was provided at a concessional price to every individual, was carried out by the state-controlled scheme of imports and the distribution of subsidized rice through 'ration shops' (Edirisinghe, 1985). Producer incentives were safeguarded through large investments to develop irrigation facilities, research and extension services, and the institution of a guaranteed procurement price for rice. The growing budgetary burden of the rice-ration scheme forced its eventual elimination following many attempts at reform.

The Rice Production System

Rice cultivation in Sri Lanka is heavily dependent on the availability of rainfall. The agricultural land is divided into wet, intermediate, and dry regions depending on the amount of rainfall received (Fig. 2-1)[5]. The wet zone which covers the southwestern quarter of the island receives sufficient rainfall to practice agriculture without irrigation. Plantation crops are concentrated in this area with low-lying areas and valleys used for rice cultivation. In the dry zone, the highly seasonal weather pattern has restricted crop production to irrigable areas. Large areas have been developed for irrigation using a network of reservoirs and irrigation channels. Roughly two thirds of the area developed for rice cultivation is located in the dry zone. A major portion of the land developed for irrigated rice production in recent years is land traditionally used for upland crop production. These lands have been developed for rice cultivation by connecting to irrigation structures built to hold water year round.

[5] The 'intermediate' zone reflects conditions in the dry zone in many respects and is often treated as a part of the latter. The same convention is followed in the discussion below.

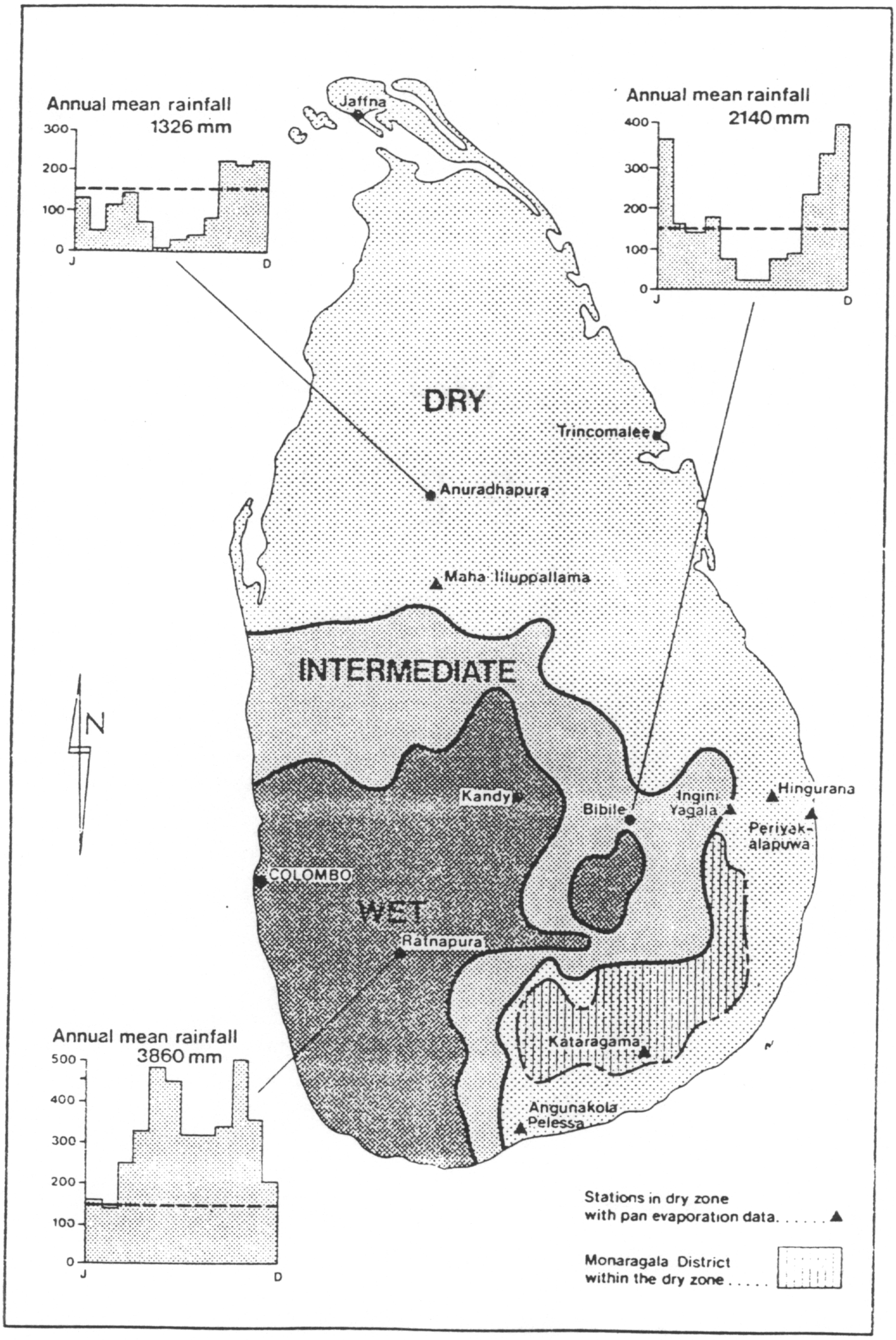

Fig. 2-1. Map of Sri Lanka Showing various Climatic Regions

Two rice crops are cultivated in a year following the seasonal pattern demarcated by the two monsoon-rainfall systems. The main (maha) crop follows the northeast monsoon (harvested in March-April), and the largest amount of land in both the wet and dry zones is planted during this season. The minor (yala) crop follows the southwest monsoon (harvested in August-September). The rice area planted during yala is less than a half of that of the maha season due to the limited amount of rainfall received and the restricted availability of irrigation water.

Government Role in Rice Production

The dry zone historically served as the grain basket of the country by bringing large areas of land under rice cultivation through an intricate network of reservoirs (called 'tanks' locally) that held runoff water during monsoonal rains to support agriculture through the extended dry season. Major investments in agriculture during the initial period after independence were thus directed to renovation and expansion of old irrigation schemes ruined by neglect. This strategy quickly matured into a system of installing new irrigation capacity through undertaking new irrigation systems. Sri Lanka continued the policy of immense irrigation modernization and expansion until the mid-1980s when its limits were imposed as a result of increasing costs of development against declining profitability of such investments (Aluvihare and Kikuchi, 1991).

The policy of building up irrigation capacity was complimented by strengthening the relatively under-developed research and extension system for food crop production. These investments received a boost from green revolution technologies which donor contributions made readily accessible. The scale and quality of services available were vastly expanded through the addition of a network of new facilities and staffing.

In the area of pricing and marketing policy, the principal means by which the state mandate was executed were rice sales to consumers through 'ration shops' and procurement of produce under the guaranteed price scheme by the state Paddy Marketing Board (PMB). Although the exact nature of the program was modified periodically to suit the changing political needs, the basic premise of the ration-book scheme was to guarantee the availability of a quantity of food adequate to maintain basic needs (Edirisinghe, 1985). Under the food-ration scheme, all members of the household were entitled to receive a specified quantity of rice (and other food commodities), at a concessional price below the going market rate. Rice issued under the scheme was imported by the food department or locally procured under the guaranteed price scheme.

Procurement under the guaranteed price scheme (GPS) assured producers a stipulated price, provided minimum quality standards were met. The PMB executed the state mandate, maintained its own network of stores for purchase and storage of paddy (rough rice), and operated several large mills. Direct purchases through the PMB stores installed in the major producing areas and the state retail cooperative stores that functioned as agents of PMB, were the primary means by which paddy (unmilled rice) was procured. Private millers were not barred from competing with these agencies except during parts of 1974 and 1975 when only the PMB was authorized to procure paddy in the open market. Procurement by the PMB accounted for a small portion of the total output, storing only about 25 percent of the output at its peak. However, this represented a significantly large portion of the marketed surplus, which was presumably much smaller than the total output.

The pricing of rationed rice and imported wheat flour were important factors in maintaining the producer price close to desired levels. As imports of rice, wheat flour and other important food stuffs were virtually under a state monopoly, this price maintenance was not too difficult to implement. The determination of the procurement price was linked to the cost of production as well as to the cost of rice procurement in the international market (although ad-hoc increases aimed at satisfying political patronage were not rare). It is evident that the incentive available to the producer in the form of a margin between the cost of production and the guaranteed price has narrowed over time, more so in the last decade. The open market price of rice in recent history has remained well above the GPS. Following the economic liberalization measures undertaken after 1977, and the elimination of the rice ration scheme in 1978, the usefulness of the GPS declined and with that the key role the state played in rice marketing. Over the last 5 to 6 years, procurement by the PMB has been less than 1 percent of the output. This exemplifies the state satisfaction with both the competitive conditions prevailing in the market as well as the level of supply.

The major inputs for rice production were also subjected to heavy state regulation in the past. Domestic sales of chemical fertilizer, which are primarily imported, received a hefty state subsidy. In 1985, the total outlay for the fertilizer subsidy was in excess of Rs. 1.3 billion, less than 1 percent of GDP. Since then funds utilized to grant the fertilizer subsidy declined sharply parallel with the decline in international prices. In 1990, the fertilizer subsidy was eliminated completely. High-yielding paddy seed produced by the Department of Agriculture was issued at a subsidized price until a few years ago. This subsidy has been scaled back following measures taken to ensure cost recovery in government operations and to increase private sector participation in seed supply. Imports of agricultural machinery are subjected to concessional tax rates to keep the costs down.

Along with a changing economic philosophy and the policies followed by successive governments, the nature and scale of producer incentives have been fully transformed over the four decades since independence: starting from economic policies that favored relatively free trade, to a very highly protected, inward-looking controlled economy, and then back to the economic liberalization and free market system (Athukorala and

Jayasuriya, 1994). The first major shift in the direction of economic policy in Sri Lanka took place after 1956 following the election of a government that pursued a path of development based on import-substitution industrialization and increased government participation in the manufacturing sector. The period of 1965-70 was characterized by a partial liberalization of the economy. In the next seven years, from 1970-77, the country reverted back to the controlled economy and import substitution policies. After 1977, significant policy reforms aimed at reinstating the open economy were undertaken by the new administration. Since then the country has adopted measures to fully liberalize the economy.

Trends in Rice Production

The post-independence growth in the Sri Lankan rice sector was outstanding. Between 1950 and 1985, rice production increased nearly six-fold from 0.30 to 2.7 million tons (Table 2-5). The growth rate was slow at the beginning but gathered momentum in the latter half of the period coinciding with the rapidly improving technology and capacity expansion. The area under rice cultivation which continued to grow through 1980s decade was a primary cause of this production growth. Also, release and adoption of new high yielding varieties of rice, use of chemical fertilizers and crop protection techniques, and expansion of high-potential land base etc. played a key role in producing this spectacular growth.

Table 2-5 **Sri Lanka: Rice production, Area Sown, Area Harvested, and Average Yield - 1966-1993**

Year	Rice Prodn. ('000 tons)	Gross Area Sown ('000 ha)	Net Area Harvested ('000 ha)	Average Yield (tons/ha)
1950	303	432	341	0.89
1955	745	545	442	1.69
1960	897	594	479	1.87
1965	764	589	432	1.77
1966	956	654	520	1.84
1967	1147	663	539	2.13
1968	1348	705	562	2.40
1969	1375	692	529	2.60
1970	1617	759	611	2.65
1971	1397	726	590	2.37
1972	1313	726	543	2.42
1973	1313	665	571	2.30
1974	1603	825	681	2.36
1975	1155	696	508	2.27
1976	1253	724	541	2.32
1977	1679	828	666	2.52
1978	1892	875	723	2.62
1979	1918	846	697	2.75
1980	2134	851	728	2.93
1981	2231	883	745	2.99
1982	2157	845	661	3.26
1983	2485	825	690	3.60
1984	2421	990	787	3.08
1985	2662	881	768	3.47
1986	2590	896	739	3.50
1987	2123	782	598	3.40
1988	2484	868	726	3.42
1989	2068	727	612	3.38
1990	2538	857	735	3.45
1991	2389	817	703	3.40
1992	2340	803	682	3.43
1993	2570	819	696	3.69

Source: Department of Census & Statistics, Sri Lanka; Department of Agriculture, Sri Lanka; National Fertilizer Secretariat, Sri Lanka

Total rice area in Sri Lanka increased by slightly more than 50 percent during 1961-1991, but what was even more significant was the increase in the share of rice area under major irrigation schemes, which increased more than 130 percent (Table 2-6). The increase in the area under minor irrigation and rainfed conditions were 35 and 20 percent respectively. This increase in the share of irrigated component in the total rice area signified a vast improvement in land quality. Also, a major share of this area growth took place in the dry zone (Fig. 2-2).

The average rice yields more than doubled during the period from 1960 to mid 1980s (Table 2-5). The highest yield growth was observed in the major irrigation areas in the dry zone. The growth in rice yields gathered speed with the introduction of early improved varieties (since then referred to as OIV's) in the early 1960's with OIVs gradually replacing traditional varieties with low yield potential. By the end of the decade, improved varieties covered over 70 percent of the paddy area, and about 90,000 tons of fertilizers were being used annually in the rice sector (Table 2-7). In late 1960s and early 1970s, new improved varieties (NIV) with a yield potential of 5 tons/hectare were released and progressively replaced with varieties possessing yield potentials over 10 tons/hectare in the 1980s. Consequently the national average yield passed the 3.0 tons/hectare level in 1981/82.

Table 2-6. **Sri Lanka: Rice Area Under Different Irrigation Regimes and Rainfed Conditions, 1966-1993**

Year	Major Irrigation	Minor Irrigation	Rainfed Area	Total Area
		('000 ha)		
1961	137	139	201	478
1962	137	142	206	485
1963	147	147	204	498
1964	148	150	208	506
1965	154	152	208	515
1966	163	157	216	536
1967	163	156	220	539
1968	168	154	225	546
1969	174	160	227	561
1970	179	162	229	570
1971	181	164	230	575
1972	184	167	236	586
1973	188	165	229	583
1974	196	169	241	607
1975	203	174	245	622
1976	204	178	248	629
1977	208	181	254	643
1978	225	186	256	666
1979	228	171	254	653
1980	235	166	253	654
1981	244	171	253	668
1982	259	172	255	687
1983	266	175	258	699
1984	269	176	258	703
1985	276	171	254	702
1986	288	176	253	717
1987	292	182	251	726
1988	298	182	248	728
1989	303	181	248	731
1990	311	179	244	734
1991	311	179	243	733
1992	317	178	241	737
1993	318	178	233	728

Source: Dept. of Census & Statistics, Sri Lanka

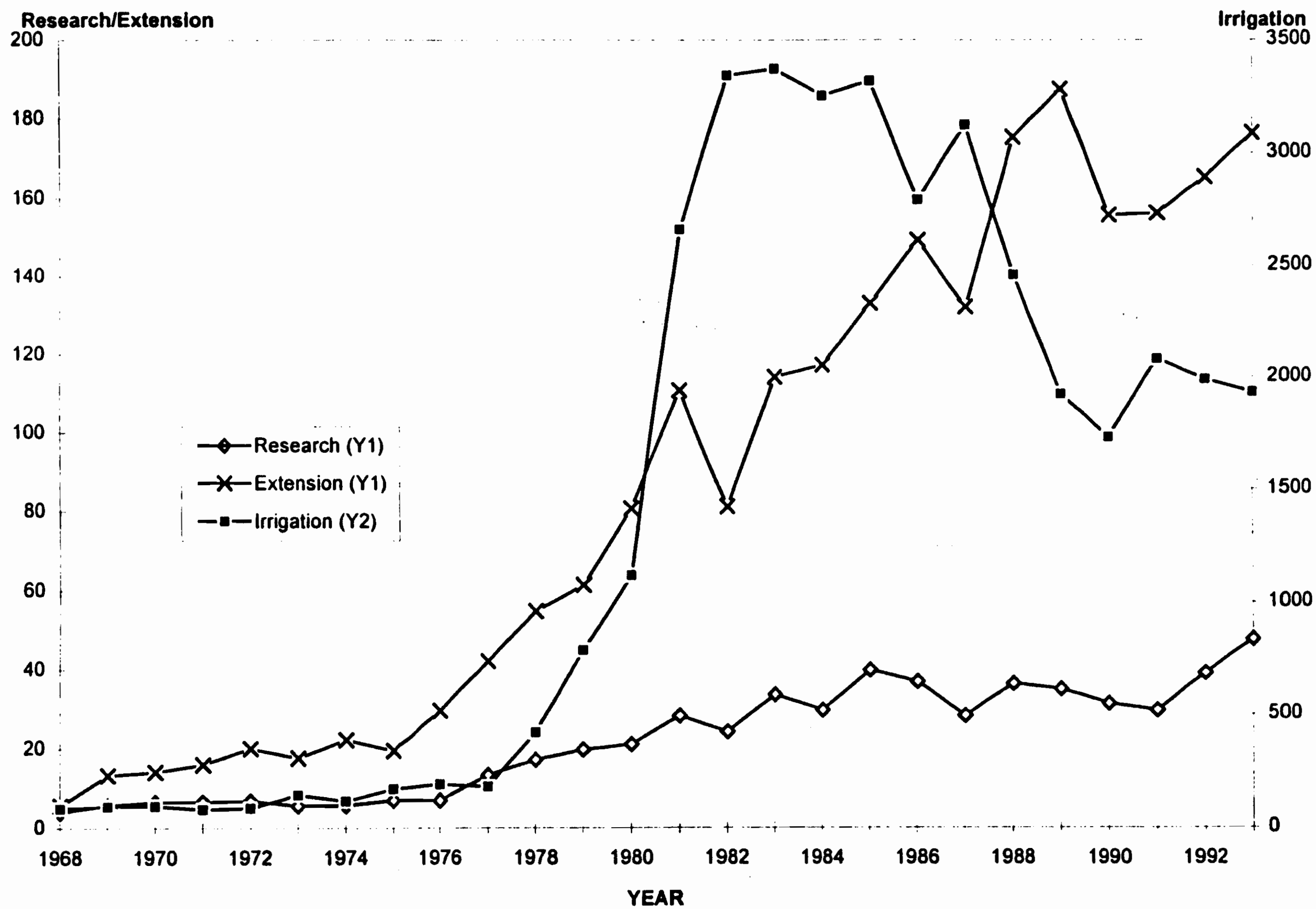

Fig. 2-3. Sri Lanka: Annual Expenditure (Rs. Million) on Rice research, Extension, and Irrigation - 1968-1993

Table 2-7 **Sri Lanka: Area Planted to High Yielding Varieties and Fertilizer Use - 1950-1993**

Year	HYV Area (percent)	Fertilizer Use ('000 tons)
1950	0	31
1955	0	53
1960	15	70
1965	42	87
1966	46	44
1967	58	73
1968	54	85
1969	66	84
1970	71	87
1971	67	95
1972	66	88
1973	70	126
1974	83	96
1975	75	49
1976	77	72
1977	84	123
1978	81	136
1979	73	130
1980	79	190
1981	90	156
1982	90	167
1983	91	162
1984	98	187
1985	98	203
1986	98	233
1987	98	217
1988	99	224
1989	99	238
1990	99	161
1991	99	179
1992	99	193
1993	99	213

Source: Department of Census & Statistics, Sri Lanka; Department of Agriculture, Sri Lanka; National Fertilizer Secretariat, Sri Lanka

However, rapid advances in area and yield growth during most of the 1960s and 1970s started to fade starting in the mid to late 1980s. The growth in area dropped to less than 2 percent, and the growth in yield nearly ended. The total planted area and the output levels that were steadily increasing until 1984 halted and even exhibited a declining trend thereafter. The target of rice self-sufficiency which once appeared within easy reach had suddenly become elusive.

Several developments in the policy arena separate the period after 1980 from that before. The expansion in irrigated area was made possible by huge investments in new construction and rehabilitation of ancient irrigation systems that were highly profitable. However, rising costs of irrigation and declining rice prices in real terms significantly limited the profitability of all types of irrigation expansion. In Sri Lanka, the cost of capital investment for construction of new irrigation systems increased fourfold over two decades, from $ 1470/hectare in 1966-69 to $ 5776/hectare in 1986-88 (Aluvihare and Kikuchi, 1991). Consequently, funds available for irrigation expansion were sharply cut back (Fig. 2-3). The growth rate in irrigation investments which was at its peak in the late 1970s and early 1980s dropped sharply since mid-1980s.

The other major area of technology improvement, rice research and extension, also suffered from declining international rice prices. The growth rate of annual government expenditure on rice research and food crop extension started to slow down in the late

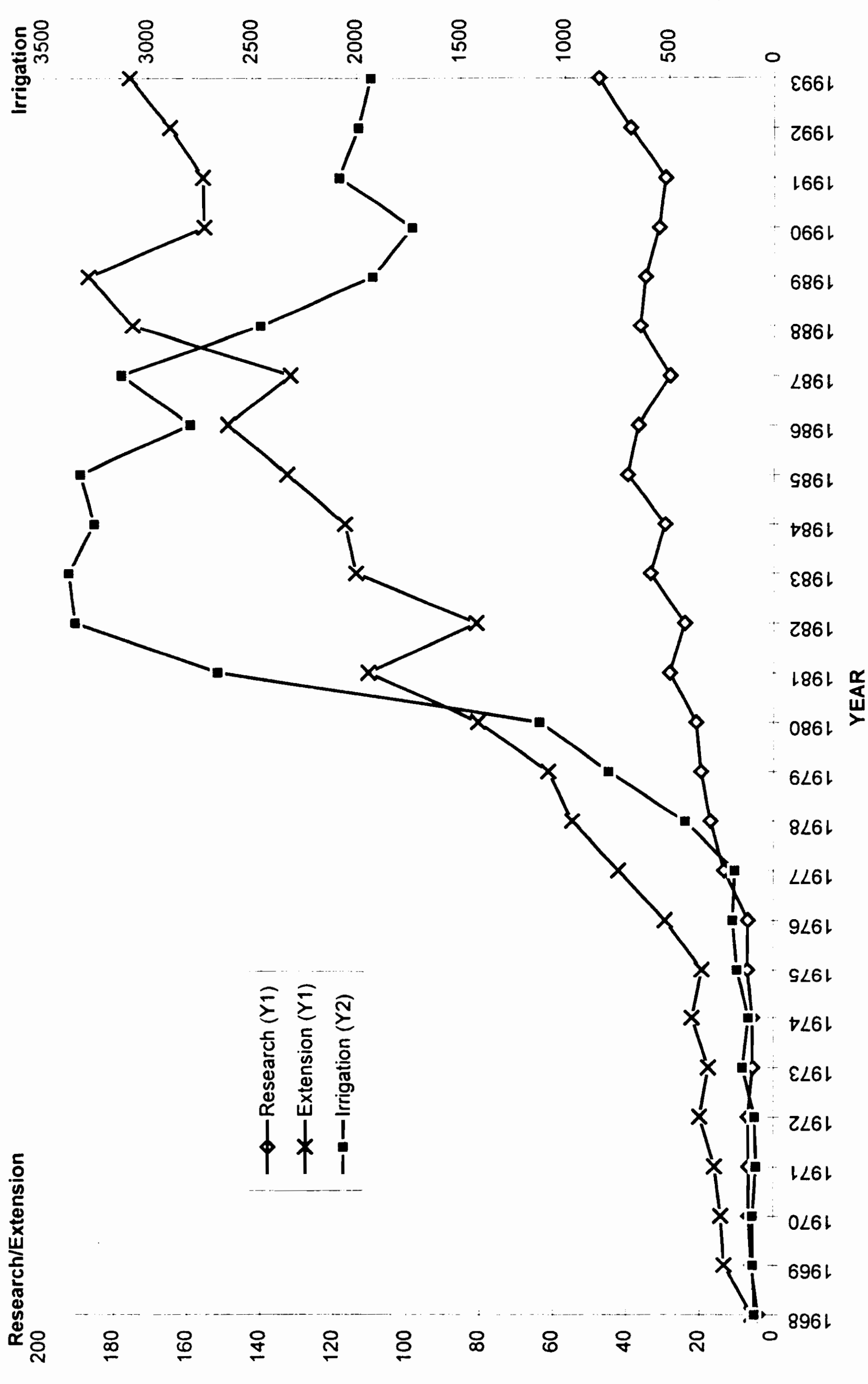

Fig. 2-3. Sri Lanka: Annual Expenditure (Rs. Million) on Rice research, Extension, and Irrigation - 1968-1993

1980s (Fig. 2-3). The decline in rice prices and demand shifted attention towards feed and horticultural crops as potential alternatives for increasing farm incomes. An increasing share of new and existing investments were diverted toward non-rice research and extension activities. The aggregate impact of rolling back investments affecting rice has no doubt played a role in creating the present situation.

Other far-reaching changes have occurred in the realm of economic policy. In an effort to reduce the fiscal deficit, the government has introduced a series of reforms in recent years seriously curtailing the incentives available to rice producers. One of the earliest casualties was the subsidy on fertilizer that was fully withdrawn in 1990. To encourage private initiatives and to reduce wasteful expenditure in seed production, state programs for seed paddy production and distribution were sharply curtailed. Measures were also taken to curtail state involvement in rice marketing by eliminating the PMB. Many of these reforms were essential in the light of changes in the world rice market and the new economic strategy of the government. However, these reforms have reduced significantly the incentives available to the rice producers. Thus, it is not unexpected that domestic rice production would decline with far reaching implications on rice prices, consumption and trade.

Trends in Domestic Food Consumption

Due to the accelerated growth of the rice sector during the last 15 years, Sri Lanka has managed to maintain its per capita rice consumption at a constant level with sharply reduced import levels. Annual per capita rice consumption has remained around 100 kg. despite the population growth at a rate of about 1.7 percent per year. Today domestically produced rice constitutes 90 percent of the volume consumed annually, as against 56 percent in the early 1960s.

However, the trend in rice consumption only partially explains the food consumption scenario. The consumption of wheat flour gradually increased through the 1960s, and in the 1970s wheat flour supplied nearly a third of the cereals in the diet (Table 2-8). Along with the increase in domestic rice supply in the 1980s, the usage of imported wheat flour, was restricted to 1970s levels. During recent difficulties in the domestic rice supply, wheat flour imports have increased.

The retail price of wheat flour has always being a key component in the food balancing act. The retail price of wheat flour and bread are set by the government, and fixed with more consideration to its impact on rice than the actual cost of importation.

Table 2-8 Sri Lanka: Grain Balances, 1982/83 - 1991/92

Year		Supply '000 tons			Availability and Use '000 tons		
	Prod.	Imports	Food Aid	Non Food	End Stocks	Total Use	Per Cap. Use Kg.
1982/83	1,482	391	226	134	217	2,096	140
1983/84	1,704	319	203	137	312	2,183	136
1984/85	1,656	635	386	165	206	2,508	157
1985/86	1,825	575	391	197	364	2,410	151
1986/87	1,781	243	276	164	586	1,928	120
1987/88	1,460	580	366	196	535	2,455	153
1988/89	1,701	888	290	208	520	2,468	145
1989/90	1,418	764	361	144	542	2,248	132
1990/91	1,741	558	272	172	730	2,267	133
1991/92	1,640	820	231	181	658	2,381	140

Source: Adapted from Global Food Assessment, USDA. 1992

Demand for Rice in Sri Lanka

Over several decades, per capita rice consumption in Sri Lanka has stayed relatively steady between 90-110 kg per capita. This corresponds to the relatively narrow range of consumption for Asian countries where rice is the staple. Changes in rice consumption patterns in Sri Lanka were heavily influenced by government policies which control trade and the public food distribution under the rice-ration scheme. During certain periods, issues of subsidized rice under the ration scheme have accounted for over 75 percent of the rice consumed (Gavan and Chandrasekera, 1979).

Food expenditure elasticities in 1969-70 estimated by Gavan and Chandrasekera, (1979) were 0.90 for the lowest income decile of the population, and declined to 0.49 for the top income decile. The income elasticities for calories obtained from rice were 0.44 for the lowest decile and 0.24 for the fifth decile.

Analysis of food consumption patterns in Sri Lanka revealed that income elasticities of demand for rice were positive but declining with increasing income (Yetley and Tun, 1981). The income elasticities for wheat demand were similar across income groups as well as urban and rural populations (Table 2-9).

Table 2-9 **Sri Lanka: Food Demand Elasticities by Income Classes**

Income Class	Food Group	Elasticities		
		Rice Price	Wheat Flour Price	Income
Urban				
1	Rice	-0.0345	0.4110	0.5137
	Wheat Flour	0.3357	0.3788	0.5460
2	Rice	-0.3931	0.0414	0.4572
	Wheat Flour	0.0678	-0.7423	0.5353
3	Rice	-0.3166	0.0127	0.4062
	Wheat Flour	0.0067	-0.3698	0.5348
4	Rice	-0.4404	0.0232	0.4034
	Wheat Flour	0.0059	0.0084	0.4542
5	Rice	-0.4123	-0.0368	0.1601
	Wheat Flour	-0.0060	-0.1480	0.3333
Rural				
1	Rice	-0.5606	-0.5467	0.7867
	Wheat Flour	0.6757	-0.5034	0.5336
2	Rice	-0.5410	0.1005	0.4754
	Wheat Flour	0.3107	-0.4025	0.5236
3	Rice	-0.4236	-0.0257	0.3257
	Wheat Flour	-0.0362	0.4378	0.5212
4	Rice	-0.4523	-0.0399	0.1740
	Wheat Flour	-0.0371	-0.4656	0.4330
5	Rice	-0.4737	-0.0894	0.2020
	Wheat Flour	-0.0455	-0.4218	0.4224

Source: Adapted from Yetley Mervin J. and Sovan Tun (1981)

Note: Income per year in 1987 Rupees: Income class 1 < Rs.2499, Income class 2 Rs. 2500 - 4999, Income class 3 Rs. 5000 - 7399, Income class 4 Rs. 7400 - 8500, Income class 5 > Rs. 8600.

Yetley Mervin J. and Sovan Tun (1981)" Household Demand Analysis for Assessing Nutritional Impact of Development Programmes" USAID, ERS, Staff Report AGES 810806

Even though the issue of long-term prospects for rice demand is far from being resolved, some clear trends stand out. The demand for rice weaken, and for wheat strengthen with growth in per capita income and urbanization. Nonetheless, the average income levels and its distribution, in Sri Lanka and the majority of neighboring countries in Asia, have still not reached a level that is high enough to cause a declining trend in total rice demand.

CHAPTER THREE

THEORETICAL MODELS: ANALYSIS OF PRODUCERS' RESPONSE AND TECHNICAL CHANGE

Introduction

The purpose of this chapter is to review relevant empirical work and to examine the theoretical issues that encompass the major focus of the research. Salient features of models customarily employed to analyze supply response are briefly reviewed. A framework for the analysis and estimation of producer response parameters in the context of technological change induced by government policy is discussed. Finally, political economic implications of government intervention to promote technical change are examined.

Estimation of Producers' Response

The parameters of interest with respect to producers' supply response are output elasticities with respect to price and technology shifters resulting from public investments. Governments most frequently use price interventions to affect the supply of agricultural products. Thus, output supply and input demand elasticities have customarily been the focus of much research. However, measures of change in producer behavior to the adjustments in other policy variables are equally important under certain other situations. Producers' response to investments in irrigation, agricultural research and extension are of as much concern as input and output prices in this study.

There exist several alternative methodologies of supply analysis, and each one has its merits and demerits (Askari and Cummings, 1977; Colman, 1983; Henneberry and Tweeten, 1991). In general, two broad types of methodologies can be identified: econometric estimation methods and mathematical programming methods. The former is by far the more popular.

In econometric estimation, a functional relationship or a model characterizing the production situation is estimated, and the supply response parameters are either estimated directly or computed indirectly as a weighted average of input demand coefficients (Griliches, 1959 and 1960). The appropriateness of the method and the quality of results obtained are determined by the time periods analyzed, the level of aggregation, the explanatory variables considered, and the quality of the data utilized. Econometric estimation methods can be classified as direct estimation methods or as dual methods.

Direct Estimation Method

Supply response parameters are estimated by specifying and estimating a supply model to obtain the desired parameter estimates. In the model specification, changes in output or planted area are explained by a set of explanatory variables that include output and input prices, environmental variables, and other supply shifters. Single equation or simultaneous equation methods can be used for estimation.

The simple structure of the direct estimation method has allowed supply analysis to be modified to deal with situations such as dynamics of supply which causes the supply effects of a variable to be spread over several periods. An important advance in the analysis of dynamics of supply was made with the introduction of the adaptive expectations model (Nerlove, 1958). Following this lead, a wide range of factors that determine the speed and magnitude of producers adjustment such as inertia, resource fixity, institutional rigidities, and risk aversion have been explicitly incorporated into supply analysis (Askari and Cummings, 1976).

The major drawback of the direct estimation method is the weak theoretical relationship between the specified supply functions and the underlying production economic theory. Yet, their simplicity in terms of data requirements and the estimation procedure, and the possibility of fewer specification errors favor the continued use of the direct estimation method. It is also claimed to handle dynamic adjustments and formulation of price expectations better than alternative methods (Henneberry and Tweeten, 1991).

Duality Method

Duality methods, where the estimation of indirect profit or cost functions are utilized to derive supply response parameters, have become extremely popular in the most recent period. Greater flexibility in the specification of factor demand or output supply response equations provided by the dual functions permits a closer relationship between economic theory and applied economic analysis (Lopez, 1982). The indirect profit function is defined as the maximum profit associated with given output and input prices, and is specified as a function of prices and fixed factors only. The output supply and input demand functions are obtained by taking the partial derivatives of the profit function with respect to prices of output and inputs. The indirect cost function is defined as the minimum cost required to produce a given level of output at given factor prices, and is specified as a function of variable input prices and quantity of output. The partial derivative of the indirect cost function with respect to the output gives the marginal cost.

Under perfect competition, the marginal cost is equated to the price of output. This relationship gives an expression that can be solved to obtain the output supply function.

The main advantage of the dual approach is that the ability to derive factor demand and output supply functions from simple partial differentiation employing the results of the envelope theorem. This facilitates specification of flexible functional forms which imposes less restrictions on the parameters estimated (Lopez, 1982). Another advantage of the duality approach is that the derived factor demand and output supply functions are obtained from profit and cost functions under conditions that are compatible with economic theory. The indirect profit function approach estimated with farm level data avoids simultaneous equation bias because the profit, output supply and input demand functions are specified as functions of truly exogenous variables that are determined independent of the firm's behavior (Lau and Yotopoulos, 1972). Elasticity estimates with respect to the fixed factors obtained from the duality approach are considered more suitable for policy analysis because, unlike in the production function elasticities, dual estimates are derived from a system where the ratio of variable factors to the fixed factor is free to adjust.

Dual functions can provide a closer approximation to reality if the assumptions of profit maximization, cost minimization and competitive markets are satisfied. Where these assumptions are not satisfied, accuracy of results obtained by duality methods are bound to be suspect. As the duality approach is developed considering the behavior of a competitive firm, the validity of the application of the same methodology with aggregated data to derive supply parameters is not clear. Also, if the elasticity estimates obtained by applying the dual method are short-run or long-run cannot be explicitly determined. If the estimated profit or cost functions included fixed factors of production, then the elasticities are short-run.

Government intervention in agriculture has been a principal means by which changes are introduced in production systems. Econometric estimation of the influence of government policies on supply parameters has posed a major problem in applied econometrics.

In the most general form of specification, econometric methods handle government intervention by incorporating policy variables in the supply estimation. To implement this approach, each instrument of government intervention is included as an independent variable. Increased complexity of government programs and the rapid expansion in the number of policy instruments quickly eliminated this as a practical approach. In a somewhat modified approach, it has been attempted to include price and income support features of government programs as a few aggregated policy variables (Houck and Ryan, 1972). These policy variables address the issue of the relevant price for producers as a short run response, but fail to measure the effect of government influence on technological decisions.

Measurement of Technical Change

The performance of the economy or a sector depends to a large extent on the nature of the implemented technology. Economic growth is frequently associated with change in technology. However, there are several difficulties in trying to measure technological change. Technology is an abstract concept and is observed only through its implementation. At any point of time there exists several techniques that can be employed to produce a particular output. Technology consists of all the available techniques. Not all available techniques are implemented at any time.

A general formulation frequently employed to represent technical change is the specification of a production function with an explicit representation of a technology shifter, t. For a single production function with two inputs, K and L, this can be written as Y= f(K, L, t), such that,

$$\frac{\delta f}{\delta t} \geq 0 \qquad (3.1)$$

or, f is monotonically increasing with time, t. Such formulations are popular due to analytical and economic tractability, and the fact that technical change occurs over time.

This is a passive approach that attempts to quantify technical change without explaining it or deriving empirically verifiable conclusions about the path of technical change. It is stated that this approach tends to perpetuate naive assumptions that (a) producers are unable to compute optimal solutions even when they know the true functional specification of non-stochastic production technologies, and (b) changes in aggregate technology remain invariant to changes in exogenous economic variables (Fawson, Shumway, and Basmann, 1990). Furthermore, there are other difficulties. The production function is a microeconomic concept having a clear meaning when it specifies a well-defined process such as the production of a specific product under well-specified conditions. But in reality, several techniques can be employed to produce an output. Consequently, there are several production functions coexisting at any time. The available data, particularly on the input side, under most situations are not separated by techniques in sufficient detail. Therefore, even in economic analysis limited to well-defined output sectors, the technology employed in production cannot be summarized by a simple production function. This raises an issue of aggregation of production functions. A further difficulty in the aggregation problem in agriculture is created by the fact that the set of aggregating functions is endogenous to the economic system (Cavallo and Mundlak, 1982).

Choice of Technique Approach

In the choice of technique approach taken by Mundlak (1988), the point of departure is the distinction made between two concepts, technique and technology. A technique can be represented by a unique production function. The technology (T) is defined as the collection of techniques. The technology set consists of the set of all individual production functions associated with each technique. At any point in time, the economy employs one or many techniques each identifying a unique input arrangement available to producers which, when implemented, produce a specific output. Technical change is defined as a change in the set of techniques available to producers.

A change in technology takes place by the emergence of new techniques as a result of research. At any moment there is a particular set of available techniques. The set of implemented technology is a subset of the available technology. Producers following the set of prices and technology shifter variables determine which subset is implemented. This implemented technology is the subset for which actual evidence exists because technology is not an observable quantity. The methodological advantage of this approach is that it provides a model that simultaneously accounts for the set of all the techniques available and the set of implemented techniques. In a dynamic framework, the continuous generation of new techniques, or technical change, is integrated with the economic process of adopting new techniques by producers.

Thus, the choice of technique approach permits separate determination of optimal input and output combinations along a specific production function (the Intra-Technique effect), and the optimal combination of techniques (the Inter-Technique effect). This is particularly suitable for policy analysis because it preserves more information for policy analysts by tracing the impact of policy variables on production, income and other economic outcomes through their effects on intra- and inter-technique effects. Within this framework, technology and other quasi-fixed inputs are determined endogenously, facilitating examination of dynamic effects of technology, prices and investments on the determination of crop output.

Consider the following real-valued function to be a production function satisfying all regularity conditions:

(3.2) $y = f(X;\Theta)$

where y is the maximum amount of output to be produced from any given set of inputs X and where Θ represents the vector of all its parameters. Also, consider that each parameter is a function of technology shifter variables γ_i:

(3.3) $\Theta_i = f(\gamma_1, \gamma_2, \gamma_3, \ldots, \gamma_k)$.

Then, it can be concluded that the implemented technology is endogenous to the model in the sense that it depends on the set of state variables (Mundlak, 1988). The implemented technology is determined jointly by the set of all available techniques (supply of technology) and by the set of state variables. The state variables are exogenous variables that are determined outside of the firm. Moreover, under the induced innovation hypothesis, which defines technological change as a response to a change in relative factor prices, it can also be argued that the available technology is endogenous to the extent the relevant prices are considered in the set of state or technology shifter variables.

Analytical Framework

The endogenous technology framework based on choice of technique defines technology (T) as the collection of possible techniques, identified as,

(3.4) $T=\{F_j(x)\}$,

where $F_j(x)$ is the production function associated with the j^{th} technique. A production function is a microeconomic concept which describes a specific technique. Under regular assumptions, the production function is associated with a convex input requirement set. Therefore, T defines an input requirement set obtained by convex combinations of the input requirement set of the individual techniques. Within this framework, technical change can be defined as a change in T.

This approach differentiates between existence of a technology set (T), and implementation of a technology (IT) set. Implemented technology is defined as the set of all techniques actually implemented. This set implies the existence of constraints which limit the input requirement set of T, in a manner in which IT is defined as a subset of T.

Figure 3.1 illustrates an agricultural technology consisting of two techniques and two inputs. The functions Y_1 and Y_2 can be thought of as production functions for a traditional variety rice and a modern variety rice represented by their respective unit isoquants. The choice of technique by an individual farmer under the situation described here depends on the relative input prices. The isoquants associated with implemented technology (IT) are identical with Y_1 and Y_2 when $K \leq K_1$ or $K \geq K_2$ respectively, and with the linear segment MN when $K_1 \leq K \leq K_2$. In reality, the capital-labor ratio in the economy will determine if either one of the two technologies or a mixture of them will be employed in production.

The transition from a traditional technique to the modern technique can also be slowed by other resource constraints that are slow to adjust. In this case, to explain the change in output it is necessary to explain the change in the constraints that determine the pace of adjustment towards the modern techniques. Thus, an empirical production function that fails to recognize the existence of different techniques will give a distorted view of the technology it is supposedly representing. The choice of technique approach, by presenting a framework within which the coexistence of several alternative techniques and the role of factors that determine the transition process can be handled, provides a superior alternative to understand and explain the process of technical change.

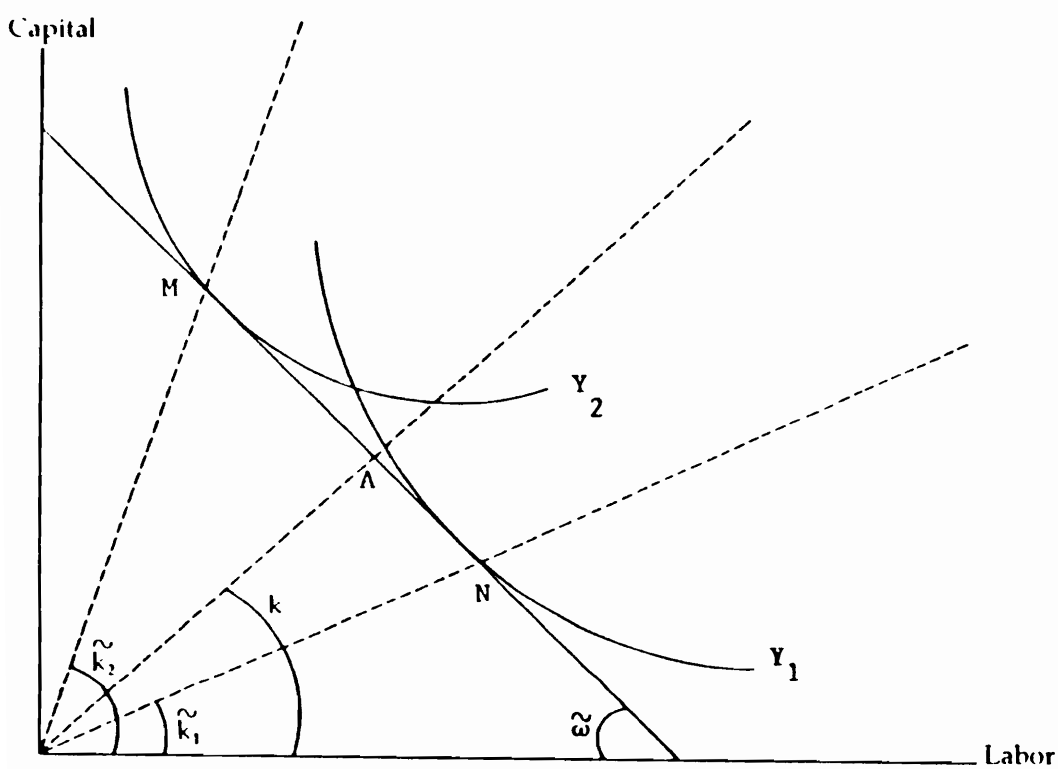

Fig. 3-1. Choice of Technique

Modeling the Single-Period Decision

The choice of technique is made at the firm level and thus the firm should be the natural starting point for formulation of the optimization problem. For simplification, consider the single period optimization problem for a single output production function consisting of fixed and variable inputs[4]. Then, the corresponding optimization problem complies with the maximization of the Lagrangian:

$$(3.5) \qquad \underset{v_i, b_i, \lambda}{Max}\ L = \sum_i p_i F_i(V_i, b_i, E) - \sum_i w v_i + \lambda(b - \sum_i b_i)$$

such that $F_i()$ belongs to the set of available technology (T); v_i and b_i are variable and fixed inputs respectively; E represents the relevant characteristics of the environment in which the technique i is implemented; p_i is the price of the product of technique i; w is the vector of factor prices; and b is the constraint on Σb_i and λ is the vector of shadow prices for the constraints b_i. The first-order conditions for the solution are:

$$(3.6) \qquad L_{v_i} = p_i F_{v_i} - w \le 0$$

$$(3.7) \qquad L_{b_i} = p_i F_{b_i} - \lambda \le 0$$

---

[4] This discussion draws on Mundlak (1986, 1988) and McGuirk and Mundlak (1991).

$$(3.8) \qquad \sum_i (L_{v_i} v_i + L_{b_i} b_i) = 0$$

$$(3.9) \qquad v_i \geq 0 \ , \quad b_i \geq 0$$

$$(3.10) \qquad L_\lambda = \sum_i b_i - b \leq 0$$

$$(3.11) \qquad \lambda L_\lambda = 0$$

where, L_{vi}, F_{vi}, L_{vi}, F_{bi}, and L_λ are vectors of the first partial derivatives. The solution to the optimization can be written as,

(3.12) $\quad v^*_i(s), b^*_i(s), \lambda^*_i(s)$,

where the exogenous variables of the problem are represented by state variables, s. The identification of the fixed factors constraining the adoption of implemented techniques is given by b. The factors identified in b represent factors that might affect technology adoption favorably or unfavorably. The set of 'positive' and 'negative' exogenous factors are represented by state variables, s:

(3.13) $\quad$ s=(b,p,w,E,T).

The choice of techniques and the level of their use are determined jointly. The number of techniques depend on a finite number of constraints (b). Available technology (T), environment (E), constraints (b), and the product and variable inputs prices determine the techniques implemented. The techniques used and the level of their use is determined by the optimal allocation of variable inputs (v^*_i) and fixed inputs (b^*_i).

The optimal output of technique i is $y^*_i = F_i(v^*_i, b^*_i, E)$.

The implemented technology, **IT**, can be described by:

(3.14) $\quad IT\ (b,p,w,E,T,) = \{F_i(v_i,b_i,E)|F_i(v^*_i,b^*_i,E)>0,\ F_i \epsilon T\}.$

Given the usual regularity conditions for F_i and for any set of state variables, the equation 3.14 describes a well-behaved technology. Consequently, a profit function can be derived:

$$(3.15) \qquad \pi(s) = \sum p_i F_i(v_i^*(s), b_i^*(s),\ E) - \sum w_i v_i^*(s).$$

The various duality conditions between profit and production functions hold true conditional on s. The frontier of IT(s) is dual to $\pi(s)$ and vice versa. By Hotellings lemma, factor demand at the technique level, $V^*_i(s)$ is given by:

$$(3.16) \qquad -\frac{\partial \pi(s)}{\partial w_i} = v_i^*(s).$$

The aggregate input demands is given by $v^*(s) = \Sigma v^*_i(s)$. Similarly, the supply of output of technique i is given by:

$$(3.17) \qquad \frac{\partial \Pi(S)}{\partial p_i} = y_i^*(S)$$

If there is more than one technique for producing a given crop, then

(3.18) $$\frac{\partial \Pi(s)}{\partial p_j} = \sum_i y_{ij}^* = y_j^*$$

where y^*_{ij} is the i^{th} technique used to produce the j^{th} crop and y^*_j is the total output of crop j. The aggregate value of supply is given by:

(3.19) $$y^*(s) = \sum p_j y_j^*(s)$$

The analytical framework outlined above identifies two effects, a joint effect and a simultaneous effect, of a change in a state variable on the optimal level of variable inputs and outputs. The distinction is important when the technology is defined by more than one technique. The first, referred to as intra-technique effect, leads to variations in the optimal combinations of inputs and outputs along a given production function. The second, inter-technique effect, leads to changes in the optimal combination of techniques represented by $F(x^*,s)$. For example, changes in prices generate variations in inputs and outputs through the intra-technique effect and a different set of implemented techniques through the inter-technique effect. This intra-technique effect is the effect usually considered in supply analysis. Because, the impact of the two effects of a change in a state variable on the output of a crop that can be produced by employing more than one technique can be very different, this differentiation is important to fully understand the changes in output.

Sequential Decision Framework

Within the choice of technique framework, the sequential nature of decision making taking place at the farm level can be incorporated into the analysis. For example, in farming, the area allocation decisions and the crop management decisions that determine yield take place at different stages. In the first stage, decisions are made on the allocation of area among the different crops and the techniques implemented from the set of available technologies, based on the information set available at the time of planting. Any subsequent changes in the output, made in response to changes in the information set that leads to revised price expectations, can only be implemented by influencing the intensity of crop management. Thus, yield determination is the second stage of the single period optimization decision represented by the profit function. Separate identification of the optimization problems by the two stages permits specification of the optimal output as the product of area and yield and their separate estimation (McGuirk and Mundlak, 1991).

This sequential nature of the decision is implemented in the model by including the area allocation decisions taken at stage I as state variables for stage II decisions. Suppose that the vector of state variables in stage I of the optimization problem is represented by,

(3.20) $S^1 = (b^1, p^1, w^1, E, T)$,

where b^1, p^1, w^1 are the constraints, expected prices of outputs and input prices at planting time, respectively. For stage II optimization, the state variables are b^2, p^2, and w^2. Now

b^2 contains the area allocated to each technique in stage I instead of the total area available before planting, and p^2 and w^2 become producers' revised price expectations. This change allows specification of the optimal output in stage II as functions of S^1 and S^2. The optimal output is now specified as;

$$(3.21) \qquad Q^*_i = F_i\,(A_i(S^1),\, v_i(S^1,S^2),\, b_i(S^1,S^2)).$$

If the production function is assumed to have constant returns to scale in the inputs, the above equation can be specified and estimated as the product of area and yield functions;

$$(3.22) \qquad Q^*_i = A_i(S^1)\; Y_i(S^1,S^2).$$

This specification represents reality more closely than directly estimating output by allowing the producers more flexibility to revise the intensity of crop management in response to changes in the price expectations after a crop has been planted. Furthermore, under most conditions it accommodates the limitations in data availability as most of the data generated provide good estimates of area allocations by crops and techniques but are deficient in the data on allocation of inputs by stages. The assumption of constant returns to scale in inputs is not a major limitation with aggregated data.

Multi-Period Optimization

The decisions modeled so far are of a short run nature, as the techniques are chosen to optimize the output within a crop season. The choice of technique framework can be integrated into a recursive formulation of the decision problem that incorporates the long-run decisions caused by the existence of fixed inputs into the analysis (Mundlak, 1986). This is implemented by considering the inter-temporal optimization problem created by a decision to alter the availability of a fixed input (McGuirk and Mundlak, 1991).

The single-period optimization framework treats the level of quasi-fixed inputs as exogenously determined. In reality the producers decisions to arrange the level of usage of quasi-fixed inputs are made in a multi-period setting in which the anticipated effects of the changes in these inputs are considered over the lifetime of the investment. In order to endogenize the decisions that determine the level of quasi-fixed inputs, a dynamic formulation is introduced (McGuirk and Mundlak, 1991).

Consider the multi-period optimization problem for a single-output production function, $Q = F(v, K, T)$, where v is the variable input, K is the quasi-fixed input and T is technology. Assume that there are no internal costs of adjustment of quasi-fixed inputs. Then, the net cash flow of a competitive firm is;

(3.23) $R(t) = p(t)\, F(K(t),v(t),T) - w(t)v(t) - q(t)[K'(t) + \delta K(t)]$,

where, q is the supply price of capital, δ is the rate of depreciation of K(t) and other variables are as already defined.

The time path of the inputs that maximizes the present value of the revenue stream R(t) can be represented by an inter-temporal optimization problem. For a discount factor r and the vectors of variable and quasi-fixed inputs v(t) and K(t), the optimization problem is to;

$$(3.24) \qquad Maximize \int_0^{\infty} e^{-rt} R(t)\ dt,$$

subject to the initial condition $K(0) = K_0$, and the transversality condition

$$(3.25) \qquad \lim_{t \to \infty} [e^{-rt} R(t)] = 0.$$

The first-order conditions for the solution with respect to the variable inputs are;

$$(3.26) \qquad \frac{\partial R(t)}{\partial v(t)} = 0, \qquad \frac{\partial F(.)}{\partial v(t)} = \frac{w(t)}{p(t)}.$$

The Euler equation is,

$$(3.27) \qquad \frac{\partial R(t)}{\partial K(t)} - \frac{\partial}{\partial t}\left(\frac{\partial R(t)}{\partial \dot{K}(t)} \right) = 0.$$

The first-order conditions for the variable inputs (equation 3.26) indicate that the optimal input levels are determined in each period by equating marginal product to real price in that period. Therefore, revenues in subsequent periods are independent of input usage in the periods before it. This permits the optimization problem to be solved recursively. The optimal levels of variable inputs ($v^*(t)=v(s(t))$, and quasi-fixed inputs $K^*(t)=K(s(t))$, where s(t)={p(t), w(t), K(t), T) substituted back in the revenue function of the firm (equation 3.15), lead to the derivation of a restricted profit function, $\pi(s)$. Then, the second stage of the optimization is to;

$$(3.28) \qquad Maximize \int_0^{\infty} e^{-rt} \left(\pi(s) - q(t)[\dot{K} + \delta K] \right) dt.$$

subject to the constraints similar to those before. The optimal time path for K(t) is given by,

$$(3.29) \qquad K^{*}(t) = \frac{\partial \pi}{\partial K} - q\ (r + \delta) - q^{*} = 0,$$

where q^* is the time derivative of q. The optimal level is given by the point that equates value marginal productivity of the quasi-fixed input to its user cost. Since K^*=K(z), where z = {s, r, q, q^*, d}, the exogenous variables of the investment decision, a change in prices forces adjustments in K^*.

Within the choice of technique framework, this adjustment is implemented by using the profit function (equation 3.15) in place of the $\pi(s)$ in the second stage optimization (equation 3.24). The time path of the quasi-fixed input determination along with the two components of the first-stage optimization, i.e. area allocation decision and the yield determination, leads to a three-stage optimization framework outlined in the empirical specification in Chapter four.

Determination of Quasi-Fixed Inputs

The choice of technique approach outlined above characterizes technology as a collection of techniques. Technological change is achieved by a change in the set of available techniques. Technical change is possible only if new basic knowledge is produced and transferred to applied knowledge. The supply of new technology requires access to resources. Therefore, the level of production is dependent on the availability of resources. The required resources have to be supplied in various forms of capital including physical and human capital.

The level of quasi-fixed inputs are considered fixed in the short run. The pace of long run growth in output is determined by the implemented technology. The subset of implemented technology is determined subject to the levels of constraints, quasi-fixed inputs, and other exogenous variables, identified by the state variables. The state variables include contracted or committed capital, overall capital stock, the rate of capital accumulation, production and factor prices, and expectations of those prices. Changes in these prices cause changes in the implemented set.

When the levels of quasi-fixed inputs are fixed in the short run, an increase in the demand for agricultural products causes an increase in shadow prices of the constraints. The increase in shadow prices leads to more resources to move into the agriculture sector.

Because the supply of investible resources is limited, the movement of resources into the agricultural sector is determined by factors such as the overall level of resource availability and the profitability of agriculture relative to other economic sectors. More favorable values for the expected rates of return are likely to result in higher investments. Because prices are influenced by government policies, the movement of resources is also determined by changing government policies.

Inter-sectoral Allocation of Capital

The allocation of capital for the development of new technology and other state variables is implemented through decisions on new investments. The possible expansion of capital stock is limited by the size of the gross domestic investment. The sectoral differences in capital allocation depends on the relative profitability of capital in each sector.

It was shown above that movement of capital into the agricultural sector takes place within a competitive environment that takes into consideration the potential rates of return. However, to implement this type of analysis, data are required on expected sectoral returns, cost of investment funds etc. Such data are in general not available, and some indirect representation of the above variables have to be employed (Cavallo and Mundlak, 1982). The size of investment is positively related to the stock of capital simply because of the maintenance or replacement requirements. It will also be related to stock of investible resources available. In empirical analysis it is common to use average or marginal production of capital to represent the differences in the sectoral rate of return. Due to limitations, in empirical analysis, inter-sectoral resource movements are often explained by variables representing simple measures of the relative profitability among economic sectors, changes in the overall level of resources, and additional demand influencing factors.

Political Economy of Technical Change

From the discussion above, it is clear that government policies that affect the agricultural prices may also affect the flow of resources into the agricultural sector. Governments may choose to intervene in agriculture for economic efficiency or distribution reasons. Many of the investments in the agricultural sector are of a public good nature. Cost-reducing public good inputs like crop and animal research, education and extension, irrigation development, storage facilities, roads etc., are commonly employed in agricultural production. It is widely acknowledged that governments have a decisive role to play in agriculture in dealing with issues such as rural development, poverty alleviation, guaranteeing food security, etc. (Timmer, 1991).

Governments often intervene in the provision of these inputs, because under-investment in public good inputs occur under perfectly competitive markets as individual firms cannot appropriate for itself the full economic benefit of such technology (de Gorter and Zilberman, 1990). Government policies are determined by taking into consideration the social returns to investment while farmers consider only private returns. Furthermore, many of these inputs possess scale economies that cannot easily be exploited by capital constrained, small, domestic private institutions. It is seen that many of the investments leading to technical change are of the type that invites vigorous government intervention.

Often, analysis of agriculture policies overlook interdependencies among various policies and the policy formulation process. Most policies affect performance of other policies. Research policies affect income support or supply control programs. Isolated evaluation of policies that are closely related can lead to misleading results. For example, when assessing the economic impact of investments in agricultural research, failure to account for price-distorting policies has been found to potentially bias the results (Oehmke, 1988; de Gorter and Norton, 1988; de Gorter, Nielson, and Rausser, 1992).

Empirical evidence of various interest groups affecting policies in the agricultural sector have been widely documented (Huffman and Miranowski, 1981; Rose-Ackerman and Evenson, 1985; Krueger, 1991). It is also observed that the predominant nature of agricultural policies also undergo a total transformation through the process of economic growth. In a growing economy, declining importance of agriculture was observed to create a state conducive for increasing the supply of policies favorable to producers (Anderson and Hayami, 1986).

The concepts of political economy of agricultural policies outlined above need to be considered in analyzing effects of technology-related government investments in Sri Lanka. Policies and investments aimed at quickening the pace of developing and implementing new agricultural technology ranked very high among the strategies followed by all governments. The intense desire shown by the Sri Lankan governments in the 1960s and 1970s to quickly modernize agriculture can be partly attributed to severe fiscal pressures originating from consumer oriented policies and subsidies. However, with the attainment of near self-sufficiency in rice production in the mid-1980s, improved availability of foreign reserves, and the low procurement costs of imports, the interest of the state on domestic rice production has waned. As a result, government investments geared to increasing rice production have been scaled back and policies geared to reinforce investor confidence withdrawn. It is necessary to be concerned with the possible impacts of these changes in the political-economic scenario in order to fully appraise the effects of technology variables subject to state control.

Empirical Specification

The analytical framework provided by the choice of technique model is implemented by the specification of three separate blocks of equations that describe changes in quasi-fixed inputs over time, area allocation decisions, and yield determination (McGuirk, 1988, Rosegrant and Kasryno, 1992). The three blocks of equations are specified and estimated as separate systems of equations. Each equation is explained by three sets of state variables: incentives, constraints and environments.

Area allocation equations explain the total rice and other crop area allocated to various possible techniques, within the respective regions and seasons. The area sown under each of the techniques of production constitutes the dependent variable in each area equations. The state variables in the set of incentives are represented by expected revenues and input prices. The area response to a change in expected crop price will differ by technique depending on the expected productivity of the techniques. The constraints in the area equations usually consist of the availability of land, inputs and other infrastructure related variables. The environment is represented by regional and seasonal variations in weather. Thus in this specification, techniques are endogenous to the system and determined by the existing level of resources.

The yield determination equations explain the differences in yield by technique also by similar sets of state variables identified as incentives, technologies and the environment. The variables included under incentives in the yield block are output and input prices. The technology variables are represented by investments that affect the productivity of techniques, i.e. research, extension, irrigation etc. The environment variables related to seasonal weather patterns such as the rainfall will be different from the planting time rainfall. The fixed district/regional effects will be specified similar to area equations.

The block of equations describing the changes in quasi-fixed inputs includes variables identifying incentives, constraints, and the environment. The level of investments in the agriculture sector depends on the total availability of investible resources and the relative profitability of agriculture. The sectoral differences in profitability will be accounted for by expressing the profitability in agriculture relative to value-added in other economic sectors. The influence of government policies on investments decisions has to be considered in explaining the levels of quasi-fixed inputs. In Sri Lanka, major shifts in changing government policies can be tied to the governments in power at various times and represented by appropriate dummy variables.

In chapter four, the concepts developed above are used to specify an endogenous supply response model for Sri Lanka. The structure of the model and the variables included in the estimation of it are determined by the type of technological changes considered and the specifics of data availabilities. The econometric issues pertaining to estimation of similar models are also discussed in the next chapter.

CHAPTER FOUR

Empirical Model: Specification and Estimation of A Supply Response Model

Introduction

In this chapter an endogenous supply response model consistent with the theoretical considerations outlined in chapter three is specified to examine the supply behavior of Sri Lankan rice farmers. The structure of the specified choice of technique model is described in relation to the production technologies adopted in Sri Lanka. The variables included in the econometric model, their data sources, and estimation issues are discussed.

Presentation of the model

Impacts of changes in infrastructure, government policies, and technical change on the supply behavior of rice producers in Sri Lanka are the focus of the supply response analysis. The models are estimated with cross-section time-series data for Sri Lanka. The techniques of production modeled and the structure of the equations estimated are determined by the nature of the production environment and the data available. The rationale for the structure of the empirical supply response model and identification of variables are discussed below.

Supply Analysis

The last three decades represents an era of modernization in the crop sector of Sri Lanka[5]. The five percent annual growth in rice production in Sri Lanka over the period 1960-1985 was unprecedented. Area available for rice cultivation increased by more than 50 percent while area sown increased by nearly 70 percent. These accomplishments followed a series of well-targeted interventions by successive governments since independence in

[5] During colonization, Sri Lanka underwent a major transformation of its agriculture, becoming an export-oriented plantation economy from a primarily subsistence-oriented rice economy. An account of the pre-independence evolution in the agriculture sector can be found in Bansil (1971).

1948. Nearly all areas of activity pertaining to rice production and marketing were subjected to some form of state intervention in efforts to induce change.

The changing structure of the rice economy over the expansion phase has various regional implications. For example, the highest growth in area available for rice cultivation and area sown in the recent past were under the irrigated category and almost all this growth was realized in the dry zone. Gains in output were accompanied by significant growth in the use of inputs such as chemical fertilizers, high-yielding variety seed, and agricultural credit. These were complemented by sharp increases in investments in agricultural research and extension, improved marketing infrastructure, and other support services. Also of interest from a policy perspective are the responses to incentives maintained in the form of price protection for rice and other food products through the guaranteed price scheme and import controls. However, regional disparities in rates of input usage and output growth are evident despite overall growth in rice output. Therefore, it is important that the supply analysis isolates and quantifies the responses to adjustments in levels of quasi-fixed inputs and prices while recognizing regional variations in the structure. Accommodation of contrasting regional impacts of prices and other policy variables in analyzing the supply behavior of Sri Lankan rice producers separates this study from previous attempts to explain rice supply.

The Structure of the Model

The supply analysis model implied by the choice of technique framework discussed in Chapter Three consists of three blocks of equations, i.e. area equations, yield equations and quasi-fixed input equations. The three sets of equations form a block recursive system, and the equations within each block are estimated simultaneously as a system. The relationships between the specific constructs of equations for area allocation, yield and quasi-fixed input determination are delineated by the characteristics of rice and other food crop production system exclusive to Sri Lanka. Therefore, a brief discussion of regional and seasonal dimensions of the food crop production situation in Sri Lanka is presented below.

Alternative Production Techniques

Rice is planted on land especially adapted to support a submerged rice crop[6]. Depending on the source of water, rice land is classified either as major irrigation, minor irrigation or rainfed land. Irrigation schemes with a total area of 200 acres (80 ha.) or more are considered major irrigation projects. Irrigation structures in the dry zone consist of

---

[6] Land adapted for rice cultivation is traditionally referred to as 'asweddumized land' (total rice land, hereafter), which comprise rice fields that are leveled, and ridged to hold water received from irrigation or rainfall.

reservoirs (or ‘tanks’) that stock water from seasonal run-off from streams and catchment areas, while those in the wet region are largely water diversion schemes that exploit perennial streams and rivers. Rice land classified under major irrigation is located almost exclusively in the dry zone, while most of the irrigated land in the wet zone comes under minor irrigation (Fig. 4.1).

Both in wet and dry zone areas, the highest amount of rice planting is observed in the maha (literally meaning major) season that extends from September to March. In the wet zone, the amount and distribution of rainfall during the maha season often is sufficient to raise a good crop of rice without irrigation. In the dry zone, ability to raise a successful rice crop during maha season without supplemental irrigation is often uncertain. During maha, the rainfed highlands in the dry zone that are not asweddumized (adapted for rice cultivation with needed land improvements) are planted with a wide variety of food crops (usually grouped under the category of 'subsidiary food crops') and other field crops such as pulses, corn, millet, chilli, onion, and sesame. They are often planted with the first rains of the monsoon, in September, ahead of land preparation and planting activities for rice. These crops are cultivated at a relatively unsophisticated level of management compared to rice. Non-rice field crops planted in the wet zone areas during the maha season include vegetables and some subsidiary food crops.

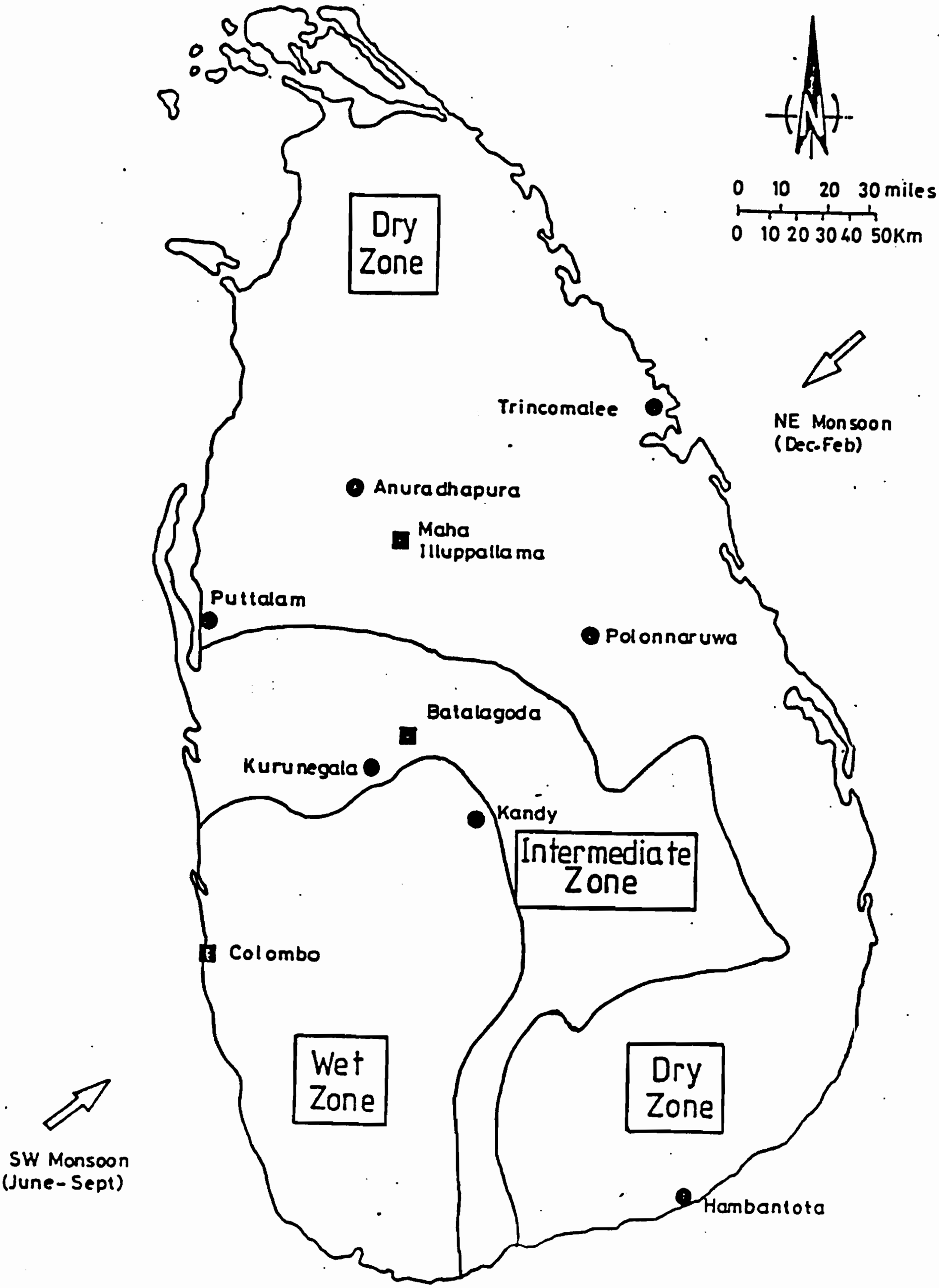

Fig. 4-1. The Wet and Dry Zones and Districts of Sri Lanka

Lower incidence of rainfall during yala season, which extends from April to August, severely limits the area cultivated in the dry region. In this region, rice cultivation during yala is mostly confined to irrigated rice fields and to a much smaller portion of the rainfed lands. Highland area planted to non-rice crops also declines sharply during yala season. Several non-rice field crops usually limited to the rainfed highlands during maha season are planted in the rice fields under irrigation when the water is available, and soil conditions and market situations favor such land use. Area planted to rice and other crops during yala season declines marginally in the wet zone.

Rice crops raised under an assured supply of irrigation water are usually managed more intensively and have greater productivity than rainfed crops. Thus, irrigated and rainfed rice lands represent a distinct land 'quality' in terms of their potentials. Crop recommendations for varietal selection, fertilizer applications and other management practices are differentiated by the cultivation season, the region, the water regimes and soil conditions, and are based on the differences in yield potential observed due to variations in growing conditions noted above. Therefore, the choice of irrigated versus rainfed rice cultivation as distinct production techniques corresponds well with the situation in the field.

Accordingly, two techniques of production for rice, i.e. irrigated and rainfed, are identified for each region during each cultivation season (Table 4.1). The distinction

Table 4.1 Classification of Cropping Techniques Included in the Analysis

Region	Land/ Water Type		Crops Cultivated by Season	
			Maha Season (Sept.-March)	**Yala Season** (April-August)
Wet Zone	Lowland	Irrigated	Rice	Rice
		Rainfed	Rice	Rice
	Highland	Rainfed	--	--
Dry Zone	Lowland	Irrigated	Rice	Rice / Cash crops
		Rainfed	Rice	Rice
	Highland	Rainfed	Cash crops	--

-- Excluded from analysis as no significant cultivations exist.

between major and minor irrigation sources within the irrigated category is ignored as this distinction is made primarily for administrative reasons and does not represent a specified quality of irrigation. The other category in the wet zone includes land planted under miscellaneous vegetable crops or left fallow. However, these crops are not important alternatives to rice. The cash crop category in the dry zone includes a select group of crops for which production shows a stronger market orientation than for the large number of seasonal crops cultivated in the region. In the maha season, the crops included in the cash crop group are maize (corn), greengram, cowpea, chilli, and soybean. In the yala season, the cash crop group includes maize, greengram, chilli, red onion, and soybean.

Empirical Specification

Based on the conditions specific to rice cultivation in Sri Lanka outlined above and the theoretical model presented in chapter three, an empirical supply response model is developed in this section. The short-run optimization, from which the area and yield determination equations are derived, is discussed first. This is followed by equations used to estimate the quasi-fixed input levels.

The Short-Run Optimization

The choice of technique framework outlined in chapter 3 presented the producer's optimization problem as a two-stage process including short-run and long-run decisions. In the short run, the farmer's single period optimization problem is to allocate the variable factors of production among various techniques, conditioned on the availability of quasi-fixed inputs in that period. Furthermore, given the sequential nature of crop production, the short-run optimization decision can be separated into planted area and yield equations, and estimated separately. Thus, at this stage of the decision process, which is conditional on a given level in the time path of quasi-fixed inputs, the production process is decomposed into area allocation and yield determination equations.

The starting point for the empirical specification of the short-run decision within the choice of technique framework is provided by the profit function specified in equation 3.15. The derivation of the profit function 3.15 assumed the existence of production and profit functions which satisfy the conditions guaranteeing duality between the profit function and the production function conditional on $\boldsymbol{s}$, the state variables identified by b, p, w, E, and T. The optimization process suggested in the choice of technique approach can be integrated with the conventional profit function specification by augmenting the profit and production functions with quasi-fixed factors, K, and other technology-related variables, Z. The variables included in Z are represented by government investments such as irrigation, research and extension expenditures. The levels of K and Z are fixed in the short run. Production and profit/cost functions augmented with technology related variables are commonly used in empirical analysis of technology impacts in agriculture (Alston, Norton, and Pardey, 1995).

Thus, in the short run, net returns to production are maximized subject to output and input prices, stocks of quasi-fixed inputs, the level of technology represented by government investments, and the environment under which the production is carried out. The general form of the profit function is

$$4.1 \qquad \Pi = \pi\ (p,w,K,Z,E),$$

where Π is the total profit so that profit is maximized with respect to a vector of fixed factors (K and Z), and subject to given input and output prices (w and p). The environment variables, E, represent the relevant characteristics of the production environment.

This specification of the profit function assumes the existence of a production function that can be specified as,

$$4.2 \qquad h(q,v,K,Z,E) = 0,$$

where q is the vector of output quantities, v is the vector of variable input quantities, K, Z, and E are defined as before. If w and p are prices of inputs and outputs respectively, the restricted profit function is given by: $p'q - w'v$. This specification assumes producer profit maximization subject to the technology constraint specified in the production function which can be specified as:

$$4.3 \qquad \underset{v,q}{Max}\; p'q - w'v, \quad s.t.\; h(q,v,K,Z,E) = 0,$$

The solution to this maximization problem can be written as a set of input demand and output supply functions given by $v=v(p,w,K,Z,E)$, and $q=q(p,w,K,Z,E)$. Substituting the above expressions for inputs and output into the definition of profit given in 4.3 gives the profit function, π:

$$4.4 \qquad \pi = p'q(p,w,K,Z,E) - w'v(p,w,K,Z,E).$$

This is the maximum profit that could be obtained given prices p and w, availability of fixed factors K, technology effects of the public investments indicated by Z, and the production technology captured in $h(q,x,K,Z,E)$.

This optimization decision for production process consisted of i techniques expressed by the equation,

$$4.5 \qquad \pi(p,w,K,Z) = \underset{h,v}{Max} \sum_i p_i\, h_i(v_i,K,Z,E) - \sum_i w_j v_i.$$

where, p is the output price vector, $h_i()$ is the production function for technique i specified by vectors of variable inputs v_i, quasi-fixed inputs K, public investments Z, and production environment E, and w_j is the variable input price vector. In this context, a technology can be taken to identify different production methods of the same crop or different crops.

Application of Hotelling's lemma to the profit function allows derivation of output supply and input demand functions solely in terms of prices, quasi-fixed inputs, government investments, and environmental factors which are:

$$4.6 \qquad \frac{\partial \pi}{\partial p_i}(p,w,K,Z,E) = q_i,$$

and,

$$4.7 \qquad \frac{\partial \pi}{\partial w_j}(p,w,K,Z,E) = -v_j.$$

The relations given by 4.6 can be utilized to specify output functions for individual techniques referred to in equation 3.17. Furthermore, as identified in equation 3.22, the output supply equation can be disggregated into an area and a yield equation in the same manner. Area and yield equations are characterized by the same arguments as in the production function.

Short-Run Empirical Model

The starting point for the specification of short-run area and yield functions is the identification of the output supply function 4.6 specified in log-linear form:

$$4.8 \qquad lnQ_t = \alpha_0 + \sum_{g=1}^{m} B_g \ln(p_{gt}) + \sum_{h=1}^{n} \Gamma_h \ln(w_{ht}) + \sum_{i=1}^{q} \Lambda_i \ln(K_{it}) + \sum_{j=1}^{r} \Psi_j \ln(Z_{jt}) + \sum_{l=1}^{s} \Upsilon_l \ln(E_{lt}) + \varepsilon,$$

where, Q_t is the output supply in period t, p_g are prices of outputs, w_h are the prices of variable inputs, k_i represents a set of quasi-fixed factors, z_j represents technology related to government investments in variables such as irrigation, research, and extension, E_t represents relevant environmental characteristics, and ϵ is the error term.

The choice of a functional form for the production and profit functions is a widely discussed topic (Fuss, McFadden, and Mundlak, 1978). Although log-linear functions are non-flexible, they are widely used to specify production environment due to empirical reasons such as convenient interpretation, parsimonious in parameters etc. (Basmann et al., 1988; Swami et al., 1989; Fawson, Shumway, and Basmann, 1990). Most importantly, specification of endogenous technical change hypothesis in log-linear environment allows for consistent modeling structure. The studies by Cavallo and Mundlak (1982) and McGuirk and Mundlak (1991) used the log-linear specification.

In the conventional profit function approach, systems of output supply and input demand functions or share equations derived from the specified profit function are estimated (Evenson, 1984; Bapna, Binswanger, and Quizon, 1984; Fulginiti and Perrin, 1990). The estimation of input demand functions for rice in Sri Lanka is not attempted due to paucity of data on input usage.

Following the choice of technique approach, the optimal output under a technique i is specified as the product of area and yield functions $i.e., q_{it} = A_{it} * Y_{it}$. Seasonal area and yield functions for selected techniques are estimated separately for the dry and wet regions of Sri Lanka. Empirically specified area and yield equations are presented below as are definitions of variables. The details of the computation of variables used in estimation are described under measurement of variables in the section following the model specification.

Area Equations:

The set of area functions describes the allocation of total (asweddumized) rice area among different techniques. The independent variables in the area equations are incentives represented by crop and input prices, constraints, technology related variables, and the environment. Following the discussion above, the area function for a technique i is specified as:

$$4.9 \qquad lnA_{it} = \alpha_0 + \sum_{g=1}^{m} \beta_g \ln(p^*_{gt}) + \sum_{h=1}^{n} \gamma_h \ln(w^*_{ht}) + \sum_{i=1}^{q} \lambda_i \ln(K_{it}) + \sum_{j=1}^{r} \psi_j \ln(Z_{jt}) + \sum_{l=1}^{s} \varphi_l \ln(E_{lt}) + \varepsilon,$$

where p^* and w^* are normalized prices, and others are as defined in the output supply function.

Area functions are specified for the wet and dry regions separately. The cropping techniques in the wet zone consist of rainfed and irrigated rice since there are no other crops of importance. In the dry zone, an additional 'cash' crop category is included to account for the large upland area planted to non-rice crops. Including the two cropping seasons *i.e.*, maha and yala, there are four blocks of area equations.

In the empirical specification of the area functions, incentives are represented by expected net revenues. This representation is used for two reasons. The study examines the choice between two techniques (separated by land of different quality) that are used in the production of a crop which receives the same output price. Secondly, due to constant changes in revenue levels introduced by changing technology, expected revenue was considered more relevant than price alone in explaining area decisions. In supply response studies, expected revenues have often been used instead of prices to represent incentives (McGuirk and Mundlak, 1991: Kumar and Rosegrant, 1993).

Expected revenues are estimated as expected gross revenue calculated as the product of expected yield and expected price less the costs of fertilizer and power. The details of calculation are presented below under measurement of variables. Expected revenues of all alternative techniques available in a region during a given season are included in all area equations to capture the influence of changes in relative earnings between different techniques on the area allocation decision. In the dry zone, relative earnings influence choice of technique (*i.e.*, irrigated vs. rainfed) as well as between-crop choice of technique (*i.e.*, rice vs. cash crop). When farmers have a choice between planting irrigated and rainfed rice, and/or rice and cash crops, changes in relative earnings under alternative techniques can be expected to influence the area allocation decision.

The quasi-fixed inputs in the area equations are represented by total (asweddumized) rice area under irrigated and rainfed categories. Because incentives in the area equations are represented by expected net revenues, the coefficients of the variables representing input prices (w_i), and technology-related government-investment variables which influence yield are removed from the planted area equations. Since technology-related variables usually have their primary impact on the crop yield, the short-run response to these variables is investigated by including them in the yield equations. The impact of environmental conditions is represented by pre-planting rainfall. Although the area is divided into dry and wet regions based on the overall level of rainfall, yearly seasonal fluctuations have a distinct effect on the area planted.

The sets of wet and dry region area equations specified for the maha season are presented below. The variable definitions are shown in table 4.2.

Area equations:

Maha Season - Wet Zone:

$AIWM_t = f(RIWM_t, RRWM_t, TAIW_t, RF1WM_t, Dxx, u)$
$ARWM_t = f(RIWM_t, RRWM_t, TARW_t, RF1WM_t, Dxx, u)$

Maha Season - Dry Zone:

$AIDM_t = f(RIDM_t, RRDM_t, RCDM_t, TAID_t, RF1DM_t, Dxx, u)$
$ARDM_t = f(RIDM_t, RRDM_t, RCDM_t, TARD_t, RF1DM_t, Dxx, u)$
$ACDM_t = f(RIDM_t, RRDM_t, RCDM_t, TCDM_t, RF1DM_t, Dxx, u)$

Area equations for the yala season were specified similar to those for maha season, except that the total rice area available were represented by the area planted in maha season. Yala is the minor cropping season of the two-season agricultural year, and the cultivation of rice area not planted to rice during the preceding maha season is constrained by the short turn around time available for land preparation. Also, land preparation costs of rice fields uncultivated during the preceding maha season are increased due to excessive weed growth.

Table 4.2 Variables in The Model[7]

Variable	Description
Area Variables:	
$TAIW_i$	Total rice Area Irrigated (asweddumized) in the Wet zone ('000 ha)
$TARW_i$	Total rice Area Rainfed (asweddumized) in the Wet zone ('000 ha)
$TAID_i$	Total rice Area Irrigated (asweddumized) in the Dry zone ('000 ha)
$TARD_i$	Total rice Area Rainfed (asweddumized) in the Dry zone ('000 ha)
AIW_i	Area planted Irrigated rice in the Wet zone ('000 ha)
ARW_i	Area planted Rainfed rice in the Wet zone ('000 ha)
AID_i	Area planted Irrigated rice in the Dry zone ('000 ha)
ARD_i	Area planted Rainfed rice in the Dry zone ('000 ha)
ACD_i	Area planted to Cash crops in the Dry Zone ('000 ha)
Output Variables:	
YIW_i	Yield of Irrigated rice in the Wet zone (mt/ha)
YRW_i	Yield of Rainfed rice in the Wet zone (mt/ha)
YID_i	Yield of Irrigated rice in the Dry zone (mt/ha)
YRD_i	Yield of Rainfed rice in the Dry zone (mt/ha)
YCD_i	Yield of Cash crops in the Dry Zone (mt/ha)
Revenue and Price Variables:	
RIW_i	Expected Revenue of Irrigated rice in the Wet zone (Rs/ha)
RRW_i	Expected Revenue of Rainfed rice in the Wet zone (Rs/ha)
RID_i	Expected Revenue of Irrigated rice in the Dry zone (Rs/ha)
RRD_i	Expected Revenue of Rainfed rice in the Dry zone (Rs/ha)
RCD_i	Expected Revenue of Cash crops in the Dry zone (Rs/ha)
$PRICEW_{i,t-1}$	Lagged price of rice in the wet zone (Rs/kg)
$PRICED_{i,t-1}$	Lagged price of rice in the dry zone (Rs/kg)
$PFERT_i$	Price of fertilizer at the beginning of the season (Rs/kg)
$PCASH_{i,t-1}$	Price Index of cash crops previous season

[7] Notation: An extension involving D or W in the variable name identifies the Dry or the Wet zone, respectively. A subscript 'i' denotes that the variable is defined for the Maha season (i=M), and the Yala season (i=Y) separately.

Government Investments:

$IRGN_t$	Irrigation stock in the current period
RES_t	Research stock in the current period
$EXTW_t$	Extension stock for Wet zone in the current period
$EXTD_t$	Extension stock for Dry zone in the current period

Environment:

$RF1W_i$	Pre-planting rainfall variable for the Wet region (mm)
$RF1D_i$	Pre-planting rainfall variable for the Dry region (mm)
$RF2W_i$	Immediate post-planting rainfall variable for the Wet region (mm)
$RF2D_i$	Immediate post-planting rainfall variable for the Dry region (mm)

Investment Incentives:

$RPROFIW_t$	Expected Profitability from new irrigated rice area in the Wet zone
$RPROFRW_t$	Expected Profitability from new rainfed rice area in the Wet zone
$RPROFID_t$	Expected Profitability from new irrigated rice area in the Dry zone
$RPROFRD_t$	Expected Profitability from new rainfed rice area in the Dry zone

Dummy Variables:

D7477	Dummy variable set equal to 1 for years 1974 to 1977
D7980	Dummy variable set equal to 1 for years 1979 to 1980
D8693	Dummy variable set equal to 1 for years 1986 to 1993

Error Term:

u	Unexplained variation

Yield Equations

The blocks of yield equations correspond directly to the area equations. The yield function for a technique i takes the form:

$$4.10 \qquad lnY_{it} = \alpha_0 + \sum_{g=1}^{m} \beta_g \ln(p^*_{gt}) + \sum_{h=1}^{n} \gamma_h \ln(w^*_{ht}) + \sum_{i=1}^{q} \lambda_i \ln(K_{it}) + \sum_{j=1}^{r} \psi_j \ln(Z_{jt}) + \sum_{l=1}^{s} \varphi_l \ln(E_{lt}) + \varepsilon,$$

where variable definitions are similar to those in the area equations. Crop yields are explained by normalized prices of outputs and inputs, updated quasi-fixed inputs represented by planted areas, and government investments. Fertilizer price is the only input price included in the yield equations. All prices are normalized using agricultural wage. Government investment variables are represented by the levels of their stocks in each period computed as described under measurement of variables. The environment variable in the yield equations is represented by the rainfall in the period immediately after planting.

Yield Equations:

Maha Season - Wet Zone:

$YIWM_t$ = f($PRICEWM_{t-1}$, $PFERTM_t$, $AIWM_t$, $IRGN_t$, RES_t, $EXTW_t$, $RF2WM_t$, Dxx, u)
$YRWM_t$ = f($PRICEWM_{t-1}$, $PFERTM_t$, $ARWM_t$, $IRGN_t$, RES_t, $EXTW_t$, $RF2WM_t$, Dxx, u)

Maha Season - Dry Zone:

$YIDM_t$ = f($PRICEDM_{t-1}$, $PCASHM_{t-1}$, $PFERTM_t$, $AIDM_t$, $IRGN_t$, RES_t, $EXTD_t$, $RF2DM_t$, Dxx, u)
$YRDM_t$ = f($PRICEDM_{t-1}$, $PCASHM_{t-1}$, $PFERTM_t$, $ARDM_t$, $IRGN_t$, RES_t, $EXTD_t$, $RF2DM_t$, Dxx, u)
$YCDM_t$ = f($PRICEDM_{t-1}$, $PCASHM_{t-1}$, $PFERTM_t$, $ACDM_t$, $IRGN_t$, RES_t, $EXTD_t$, $RF2DM_t$, Dxx, u)

Yield equations for the yala season are identical to those of maha season.

The Long-Run Optimization

In the long run, the level of quasi-fixed inputs can also be changed. The decisions by producers to alter the availability of quasi-fixed inputs are made taking into consideration the effects of changes in these inputs on costs and revenues over the life-time of the investment. Thus, the farmers' long-run optimization decision is an investment decision where the level of quasi-fixed inputs would be chosen to maximize the discounted future stream of rents accruing to these inputs.

The multi-period nature of the long-run optimization decision is best handled by the specification and estimation of a dynamic optimization model. However, specification and estimation of a complex long-run optimization model is often impractical due to data limitations in developing countries. Past analysis of the long-run decision within the choice of technique framework utilized a functional approach that is complementary with the data situation in developing countries (Cavallo and Mundlak, 1982; McGuirk and

Mundlak, 1991; Rosegrant and Kasryno, 1992). These specifications explain resource flow to the agricultural sector using variables that represent the relative profitability in the sector (average crop revenue, prices of outputs and inputs), existing capital stock (lagged-levels of quasi-fixed inputs), overall level of resources in the economy (per capita income), and additional factors influencing the demand (population density). An increase in the profitability of rice production relative to other crop and non-crop sectors in the economy makes it more attractive for new investments. Likewise, increases in resources available in the economy and consumer demand growth are expected to favor expansion of total rice land area which increases food production capacity.

Long-Run Empirical Model

The short-run profit function framework, augmented with technology-related government investment variables identified by *Z*, provides greater flexibility than traditional approaches in modeling the long-run decision. Farmers' long-run decision is specified as the optimal choice of total rice area (asweddumized) under different quality land. The impacts of the government investments enter the long-run optimization problem as demand shifters through T, the available technology set. Thus, the levels of irrigation, research and extension investments decided by the government are treated as exogenous to the individual farmer.

Quasi-Fixed Input Equations:

Total rice (asweddumized) area under four categories, i.e., total rice area under **rainfed** and **irrigated** rice in the **wet** and **dry** regions, are estimated in one block of equations. The four equations are specified as follows:

$$TAIW_t = f(TAIW_{t-1},\ RPROFIW_t,\ IRGN_t,\ RES_t,\ EXTW_t,\ D7177,\ u)$$
$$TARW_t = f(TARW_{t-1},\ RPROFRW_t,\ IRGN_t,\ RES_t,\ EXTW_t,\ D7177,\ u)$$
$$TAID_t = f(TAID_{t-1},\ RPROFID_t,\ IRGN_t,\ RES_t,\ EXTD_t,\ D7177,\ u)$$
$$TARD_t = f(TARD_{t-1},\ RPROFRD_t,\ IRGN_t,\ RES_t,\ EXTD_t,\ D7177,\ u)$$

The variables are defined as described in table 4.2.

Measurement of Variables

Annual cross-section time-series data for the period 1968-1993 was collected for the study. For the area and yield equations, data are processed separately for the two agro-ecological regions and two cultivation seasons. Sri Lanka is divided into 25 administrative districts. Agricultural statistics are reported for a total of 27 units including two major irrigation project areas classified as agricultural districts. Districts were assigned into two sets, i.e., wet zone and dry zone districts[8], based on the

[8] The agroecological classification includes a third region, the intermediate zone which is a narrow strip of land that separates the wet and dry regions. This area is included with the dry zone for the analysis.

congruence of the district boundaries with the border between the wet and dry zones. Although several new districts were carved out during the period under study, this did not affect aggregation as the new districts were confined within regional borders. The area aggregated to form the wet and dry regions are shown in the agroecological map of Sri Lanka in Fig. 4.1.

The primary source of data on area, production, and prices of rice and other food crops was the nationwide data collection system of the Department of Census and Statistics. Data on input use, research and extension expenditures, and rice varietal use were obtained from the agricultural statistics series of the Ministry of Agriculture Research and Development, and the Departments of Agriculture and Agrarian Services. Other sources for data were the Central Bank of Sri Lanka (for macroeconomic data), the Ministries of Irrigation, Lands and Mahaweli Development (for data on irrigation), the Food Department (for rice imports and usage data), and the Meteorological Department (for weather data).

Data on area planted, area harvested and production of rice are classified within each administrative district by the water regime (major and minor irrigation, and rainfed). Data on prices are reported for the districts on a monthly basis. The variables for the wet and dry zones were derived by aggregating the district data. The districts included and procedures adopted are described below under discussion of variables and data tables.

All monetary variables are deflated by an Implicit GDP deflator for the relevant economic sector computed from the national product statistics of the Central Bank of Sri Lanka. The data used in the analysis are given in the Appendix A tables.

Area Variables

Total irrigated and rainfed rice area in the wet and dry regions, **TAIW, TARW, TAID** and **TARD** respectively, are obtained by aggregating the total (asweddumized) rice areas in the districts included in each region. The irrigated rice area is subdivided into major and minor irrigation which is ignored in the computation of irrigated area. Data are not available on the highland area available for the cultivation of non-rice crops. Any estimates of the highland area are likely to be inaccurate due to lack of data on forest areas farmed on seasonal cultivation permits[9], and the frequent practice of 'fallowing' such land to naturally restore soil fertility. Thus, the total area available for other crop cultivation (**TACD**) was represented by the highest area cultivated to other crops prior to that season.

Rice area planted under individual techniques in the wet and dry regions (**AIW**, **ARW**, **AID**, and **ARD** variables) and the other crop area in the dry region (**ACD**) are computed by

---

[9] Such land is usually referred to as 'slash and burn' land or 'Chena' land.

aggregating the district area for each season. The cash crop group consists of maize (corn), greengram, cowpea, chilli, red onion, and soybean which are among the highland crops continuously occupying a significant area.

Yield Variables

Rice yields under each of the four techniques (**YIW**, **YRW**, **YID**, and **YRD**) are computed as the ratio of total output to the total net area harvested under the same technique in the districts coming under each region. Yield variables for cash crops in the dry zone (**YCD**) are computed by an output index because the actual output levels of the different crops aggregated under cash crops are widely different and cannot be directly aggregated. The output index was constructed following Tornquist-Theil discrete approximation which minimizes the impact of relative changes in output prices (Alston, Norton, and Pardey, 1995).

Price and Revenue Variables

Expected returns (**RIW**, **RRW**, **RID**, **RRD**, and **RCD**) are represented by the net revenue for rice and the gross revenue for other crops. The rationale for the use of net revenue as the preferred indicator of expected revenue was discussed earlier. Net revenues for techniques of rice were computed by subtracting the average costs for the last season from gross revenue (expected yield*expected price). Expected rice yields were computed either as one-period lagged yields or as a three-period moving average of the yields observed during the last 5 seasons excluding their minimum and maximum values. A moving average was chosen to smooth any short-term fluctuations, for example, due to changes in weather. The farm-gate price for the last season was taken as the price expectation. Monthly farm gate prices for rough rice (unmilled rice or paddy) are reported for all districts. The seasonal price of rice for a region (**$PRICE_{ij}$**) was computed as the average of the monthly producer prices in the major rice-growing districts in each region during the three months following the harvest. The bulk of the marketed surplus in rice is sold within three months of harvest. The districts and months included in the computation are given in the notes for Appendix Table A.5.

Average costs include costs of fertilizer and manpower including land preparation and cultivation labor. Fertilizer costs are estimated as the field cost of average amounts used in each region calculated based on usage and price data obtained from the National Fertilizer Secretariat (NFC) and cost of production studies carried out by the Department of Agriculture (DOA). District-wise fertilizer consumption for each season was estimated by the NFC until 1984. These were combined with the crop-wise fertilizer usage data compiled by the DOA for various years to estimate fertilizer usage for individual techniques up to 1984. For the years after 1984, estimates from the cost of production studies were used. Average labor requirements for the four techniques were estimated from the cost of production survey data. The agricultural wage rates for the wet and dry regions were calculated for each season. A continuous series for agricultural wages specific to the rice sector covering the full analysis period is not available from any single source. A wage series for rice for the period 1979-1993 was computed from the cost of production studies conducted by the Department of Agriculture, and the wages for the period prior to that were extrapolated using the agricultural wage series compiled by the Central Bank. The latter is based on the wages in the plantation sector, and correlated well with the observed rice wage series for 1979-1993.

A similar procedure was adopted for the calculation of the price of cash crops **(PCASH)** and the expected revenue for the group of cash crops (**RCD**). The price of cash crops was computed from the average prices over a two-month period that begins with harvest. Monthly farm-gate prices from the major cash-crop production districts were averaged and weighted by the output to obtain the relevant price (**PCASH**). The expected revenue was computed by taking the average yield for each category of cash crops in the previous three maha or yala seasons as the expected yield. A three-season average was used to minimize effects of large seasonal yield fluctuations and to prevent long-run shifts in the cash crop combinations affecting expected yields. The other price variable, (**PFERT**) is the ex-warehouse retail price of fertilizer for the city of Colombo at planting time.

Environment Variables

Seasonal fluctuations in rainfall that affect the planting area is represented by **RF1**, which represents total rainfall received at selected meteorological stations during planting months. Within the two main agro-ecological regions of wet zone and the dry zone, there are many sub-regions identified by the amount and pattern of rainfall and soil factors. Daily rainfall measurements are taken at many meteorological stations spread throughout these areas. Monthly rainfall totals for the stations that represent the rainfall pattern in the largest of these sub-regions are used to compute the rainfall variables. Rainfall totals during the immediate (first two months) post-planting period (**RF2**) are included in the yield determination equations and are compiled following the same procedure.

Stocks of Government Investments

The stock of capital and technology generation in agriculture are represented by irrigation, research and extension investments. These are the primary means by which the level of technology in the rice economy was affected over the period of study. All irrigation developments are carried out by the Departments of Irrigation and Agrarian Services, while rice research and extension were carried out by the Department of

Agriculture (DOA). The private sector role in the development of irrigation facilities is negligible. All research and extension on food crops are supplied by the government.

Historically, rice has been the exclusive beneficiary of all irrigation developments in Sri Lanka. Irrigation expansion has taken the forms of new irrigation construction, or rehabilitation of existing irrigation structures. Many of the large new construction projects included a significant 'colonization and settlement' component as well. Some other projects serve the dual purpose of water storage for power generation and irrigation. Annual outlays for irrigation development excluding non-irrigation related expenditures such as colonization and settlement, general administration, and power generation were compiled to obtain the irrigation investment (**IRGN**). Annual disaggregated expenditures on irrigation development in Sri Lanka for the period 1948-1988 were compiled by Aluvihare and Kikuchi (1991). This data series was updated for the period 1989-1993 following the Aluvihare and Kikuchi methodology.

Irrigation expenditures were converted to stocks using the formula:

$$4.10 \qquad Z_t = \overset{\circ}{Z}_t + (1-d)\, Z_{t-1},$$

where Z_t is the current stock, $\overset{\circ}{Z}_t$ is the annual expenditure during the current period, and d is the constant rate of depreciation. The rate of depreciation was estimated as 0.033 based on a average life span of 30 years for irrigation projects. Irrigation stocks from 1948 onwards were computed using annual expenditure flows. The value of initial irrigation stock in 1948 was estimated at 12,800 Rs. million. This calculation was based on the new irrigation construction amounting to 80 thousand hectares completed over the period 1929/30-1947/48 (Bansil, 1971) developed at an average construction cost of Rs. 160 thousand per hectare in constant 1982 prices.

The research and extension expenditure variables represent lagged annual expenditures by the DOA in crop research and extension activities, respectively. A bulk of crop research and extension activities of the DOA during the early years were on rice research and extension[10]. Budgetary allocations for the DOA increased significantly in the last 15 years, reaching nearly Rs. 500 million by 1993. However, an increasing share of the expenditure growth since the mid-1980s was associated with research and extension on non-rice crops. Some shift of emphasis towards non-rice crops was observed in the extension and education activities as well. But still a major share of extension activities are linked to rice production programs.

---

[10] The research and extension activities of the DOA included the functions presently carried out by the Department of Animal Production and Health before it was detached in 1978. The DOA also handled the functions of the present Department of Export Agriculture and Sugar Cane Research Institute and several other small institutions. However, the accounts were maintained separately for major sub-activities so that actual costs for non-food crop related activities could be excluded.

The expenditure on rice research was calculated as a declining proportion of total capital and recurrent expenditure on crop research activities of the DOA over 1951-1993. The weights were determined by examining changes in the expenditure on rice breeding stations relative to the total expenditure, and initiation of new projects and programs. No attempt was made to partition administrative overhead, which is relatively small and thus excluded. Since the late 1970s, an increasing portion of research and extension programs have been financed with donor funds. Expenditures under projects that were designed to promote research and extension on non-rice crops were excluded from the calculation of rice expenditures. Positive spill-ins of investments directly related to non-rice crops in the forms of general improvements to facilities, transportation, and training were disregarded due to the difficulty in quantification. The share of rice research expenditure was estimated to have dropped from 75 percent of the total research expenditure in 1970 to 40 percent by 1993. The extension expenditures are not adjusted to reflect any program focus changes since much of the activities are still tied up with rice extension.

Public investments in technology and knowledge generation are customarily represented by stocks of capital or knowledge (Alston, Norton, and Pardey, 1995). There are time lags between research investments and receipts of benefits. Also, new technologies yield benefits over a period of time and eventually become obsolete. Thus, technology variables used in econometric estimation are preaggregated following some lag-specification to account for this lagged effect as well as to decrease the number of parameters to be estimated, conserve degrees of freedom, and reduce potential problems caused by collinearity (Alston, Norton and Pardey, 1995). The procedures widely used for pre-aggregating research and extension variables are polynomial distributed lags, trapezoidal lags, DeLeeuw distributed lags, and flexible distributed lags specifically developed for the country situation. For example Pardey *et al.*, (1992) estimated flexible lags for pre-aggregating rice research expenditures for Indonesia.

The selection of appropriate lag lengths and structures for research and extension were guided by the findings of the previous studies and the conditions specific to the Sri Lankan rice sector. The determinants of lengths of lag structures is a widely discussed topic (Griliches, 1964; Evenson, 1968; and Alston, Norton, and Pardey, 1995). The determination of lag length is usually guided by a priori knowledge about the research process. The appropriate lag lengths have varied widely from six-year lags used by Griliches (1964), five to eight year lags used by Evenson (1968), and eight to seventeen year lags used by Cline (1975). Pardey and Craig (1989) performed causality tests for alternative lag lengths and concluded that long lags, 30 years or more, might be necessary to capture all of the impacts of research on agricultural output. However, available evidence suggests that somewhat shorter lags may be appropriate with a crop such as rice where the generation and adoption of new technology was rapid.

Major improvements in the level of rice technology in Sri Lanka were made available to rice farmers in the form of high-yielding varieties and improved management practices. Therefore, the schedule for the release of new varieties was also consulted to determine the appropriate lag lengths. Rice breeders in Sri Lanka were able to quickly incorporate new high-yielding germplasm into local research programs as they were identified elsewhere in Asia. From the late 1960s, new improved varieties of rice were released in quick succession to replace the improved varieties already released for use. The lag lengths for extension expenditures are generally shorter than those for research because the knowledge on new technology can be transferred to farmers faster, but also becomes quickly obsolete with the changes in technology.

The research expenditures are assumed to evenly impact on yield in both wet and dry regions in the country. The rice research system was originally based on one central rice breeding station, and expanded in the 1970s with the addition of several regional research centers. However, the national focus of the rice research program is still maintained within the network of research stations. Therefore, given the national mandate of the research system and wide geographical coverage of the varieties produced by the research system, the assumption of uniform distribution of research benefits is appropriate for Sri Lanka.

Extension stocks are computed on a regional basis by considering the numbers of extension staff allocated to the wet and dry regions and the average expenditure per extension worker. The field extension staff was allocated based on agricultural service areas in the districts. The distribution of extension staff was heavily biased in favor of wet-zone districts due to greater population in the region even though the total rice area in the region was much less than in the dry zone. Due to data limitations, the extension expenditure per region over the full period was calculated based on the average number of extension officers assigned to the wet zone and dry zone districts in the 1980s. Costs were assumed to be evenly spread per extension officer. Accordingly, 44 percent of the total extension expenditure was estimated to have been incurred in the wet zone, and the balance in the dry zone. This was converted to expenditure per 1000 hectare of rice using the total rice areas in the regions.

The appropriate lag lengths for stocks for research and extension variables were estimated using quadratic distributed lags of different lengths. The quadratic form was chosen because a priori information is not available on appropriate time weights for aggregating research and extension expenditures in Sri Lanka. Preaggregating research and extension expenditures using quadratic structure is based on the informal prior reasoning that the impact of the new knowledge arising from research and extension efforts first rises and then falls. Also, it imposes less severe restrictions than adopting other methods based on rudimentary prior knowledge. Two lag lengths of 16 and 20 years were tested to preaggregate research stocks. These lengths were guided by the lag lengths used with rice for Indonesia (Pardey *et al.*, 1992), and the conditions specific to Sri Lanka. Major improvements in the level of rice technology resulting from agricultural research were made available to Sri Lankan farmers in the form of improved varieties. Therefore, the schedule for release of new varieties was consulted to determine the lag lengths tested. Following similar reasoning, lag lengths for extension were set at 6 years. Research and extension expenditures are expressed in constant 1986 Rs. using GDP deflator.

Producer Investment Variables

The demand-for-investments specification adopted to explain decisions to expand total (asweddumized) rice area in the two regions requires some indicators of relative profitability in investing in rice production, the variation in profitability across regions, etc. A good proxy for the relative profitability is given by the value added in agriculture (or in rice production) relative to the value-added in non-agriculture. Data limitations prevented construction of a analogous variable for different regions. Instead, the profitability of new investments in rice production is represented by $\mathbf{RPROF}_{ij}$ which shows the expected level of gross returns to increasing rice area in each region. Thus, **RPROF** approximates the demand for capital allocations to rice production from changes in rice prices and productivity. RPROF was computed as the product of the expected average yield from an acre of new land and the expected price of rice. The differential impact of productivity differences existing in wet and dry zone rice production on the decision to expand the land area in the two regions is represented by this variable. These expected profitability variables were deflated by the agricultural wage rate.

Dummy Variables

The economic policies adopted by successive governments in Sri Lanka since independence have spanned the full spectrum from open-market economic policies to nearly-centralized socialist economic policies, depending on the political philosophy of the ruling party. By the late 1950s and 1960s, Sri Lanka had started to abandon the regime of open-market policies retained since independence and adopted a more inward-looking strategy to find solutions to the country's employment and food production problems. The government that was in power from 1970 to 1977 followed a policy that tightly controlled all economic activities and heavily intervened in agricultural markets. The strict import controls and rationing system adopted by the government created a situation that shifted the production incentives heavily in favor of non-rice crops while severely constraining investments and progress in the rice sector. The government change in 1977 put the country back on an open-market track. This major shift in the economic environment, particularly with respect to investments, prior to 1977 is represented by a dummy variable. The economic environment during this period was hostile towards new investments. Therefore, the dummy variable is expected to have a negative sign.

Since 1983 the north and east areas in the country have been stricken by a civil strife that affect the rice production coming from the dry zone. The levels of plantings and the yield levels have become more volatile as a result of intermittent fighting and breakdown of civil administration. The situation has become extremely volatile since 1986 after which year the reported statistics from some of the northern districts were also affected. Widespread civil unrest during the 1989-1990 affected agricultural activities in some districts. These disruptions are modeled using dummy variables. The dummy variables pertaining to these political and civil unrest years are expected to reflect the adverse conditions for investments, plantings and yields, and hence to have negative signs.

Estimation Procedure

The three blocks of equations form a block recursive system and the equations within each block can be estimated simultaneously using iterative Zellner efficient methods. The blocks of equations in the system exhibit a unilateral causal dependence, and therefore the disturbance terms in each set of equations have zero contemporaneous correlation. The equations within each block are contemporaneously correlated and have to be estimated by system methods so that parameter estimates are consistent and asymptotically efficient (Kmenta,1986; Lahiri and Schmidt, 1978).

Parameter estimation is carried out by separately estimating the three blocks of equations. The quasi-fixed equations are determined by lagged endogenous and exogenous variables. The level of quasi-fixed inputs and other predetermined variables then enter in the estimation of area allocation equations. The levels of quasi-fixed inputs and area allocations along with other predetermined variables enter in the yield determination equations.

CHAPTER FIVE

RESULTS AND POLICY IMPLICATIONS

Introduction

Estimation results for the equation systems developed in chapter four are presented below. In the first section, the nature of the data, steps used to obtain a statistically valid model prior to estimation of parameters, and estimation issues and procedures are described. A discussion of the parameter estimates and their significance for each block of equations follows. Estimates of area and output elasticities are computed, and policy implications are discussed.

Description of Data

Prior to model estimation, the data were subjected to a preliminary analysis using trend plots, cross-plots of key variable sets, and other descriptive statistics. This analysis revealed that the nature of relationships between many key variables had undergone drastic changes starting in the early to mid-1970s. The identification of the exact point of departure for the changes in variable relationships is confounded by several events that have taken place in the Sri Lankan economy since the early 1970s. These changes started with the first oil crisis during 1973-1974 which led to a severe dislocation of prices of rice and fertilizer. During the years 1974-1976, rice production in the country was severely affected by a drought in the major producing areas. In late 1977, there was a major shift in economic policies following the election of a government which instituted market-friendly policies, sharply deviating from the policies of the 1970-1977 government which relied heavily on centralized economic policies. In November 1977, a currency devaluation of nearly 100 percent was implemented. The combined effect of these successive shocks in the economy undoubtably induced many changes in the rice sector.

In general, the data suggest that a change in underlying relationships among key variables may have occurred around 1973. In every relationship plotted, the areas are substantially less for the same level of price for the period prior to 1973. The plots of

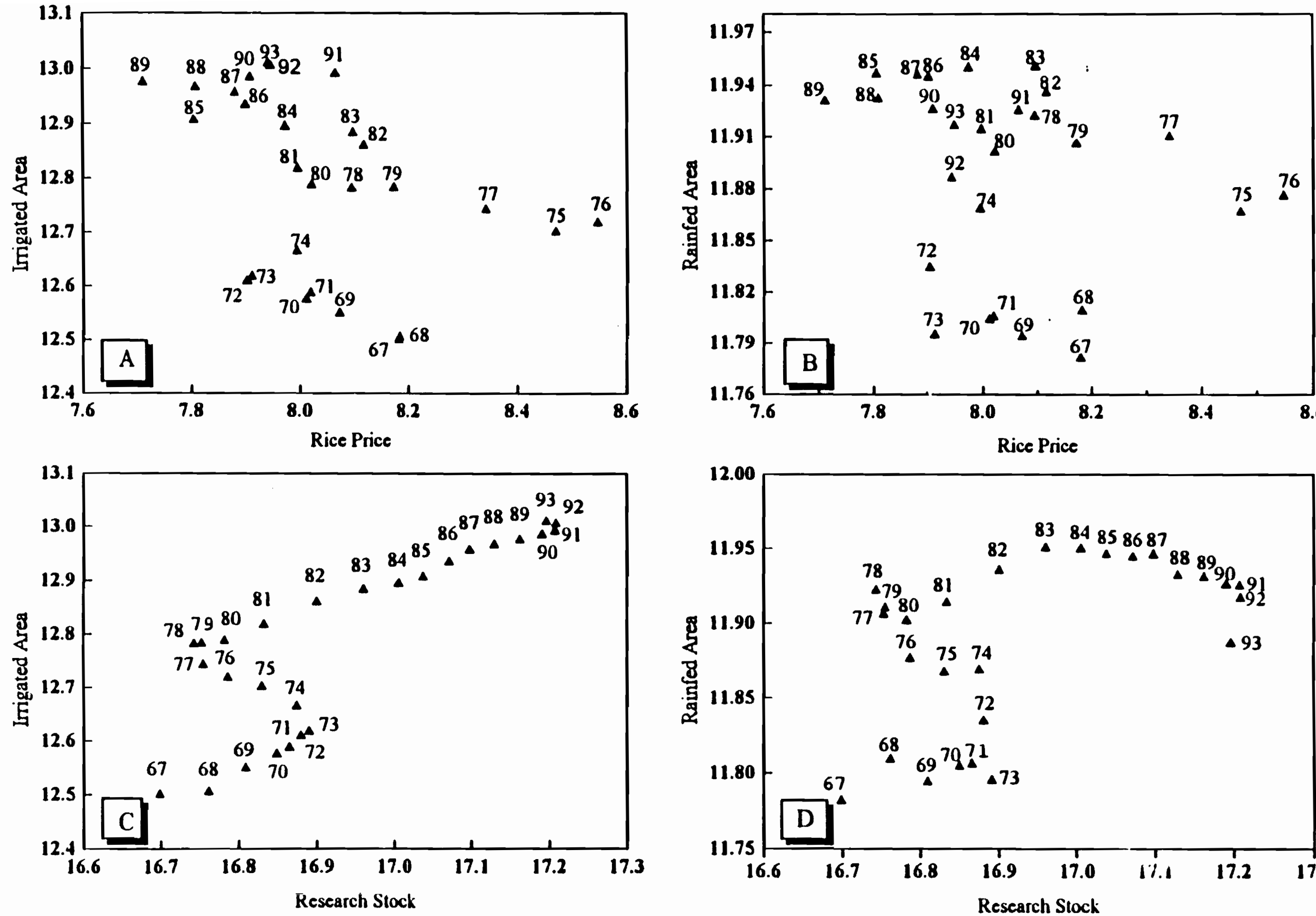

Fig. 5-1. Relationship between total rice area ('000 ha) in the dry zone and the price of rice (Rs/ton) and research stock variables (all variables are in logs).

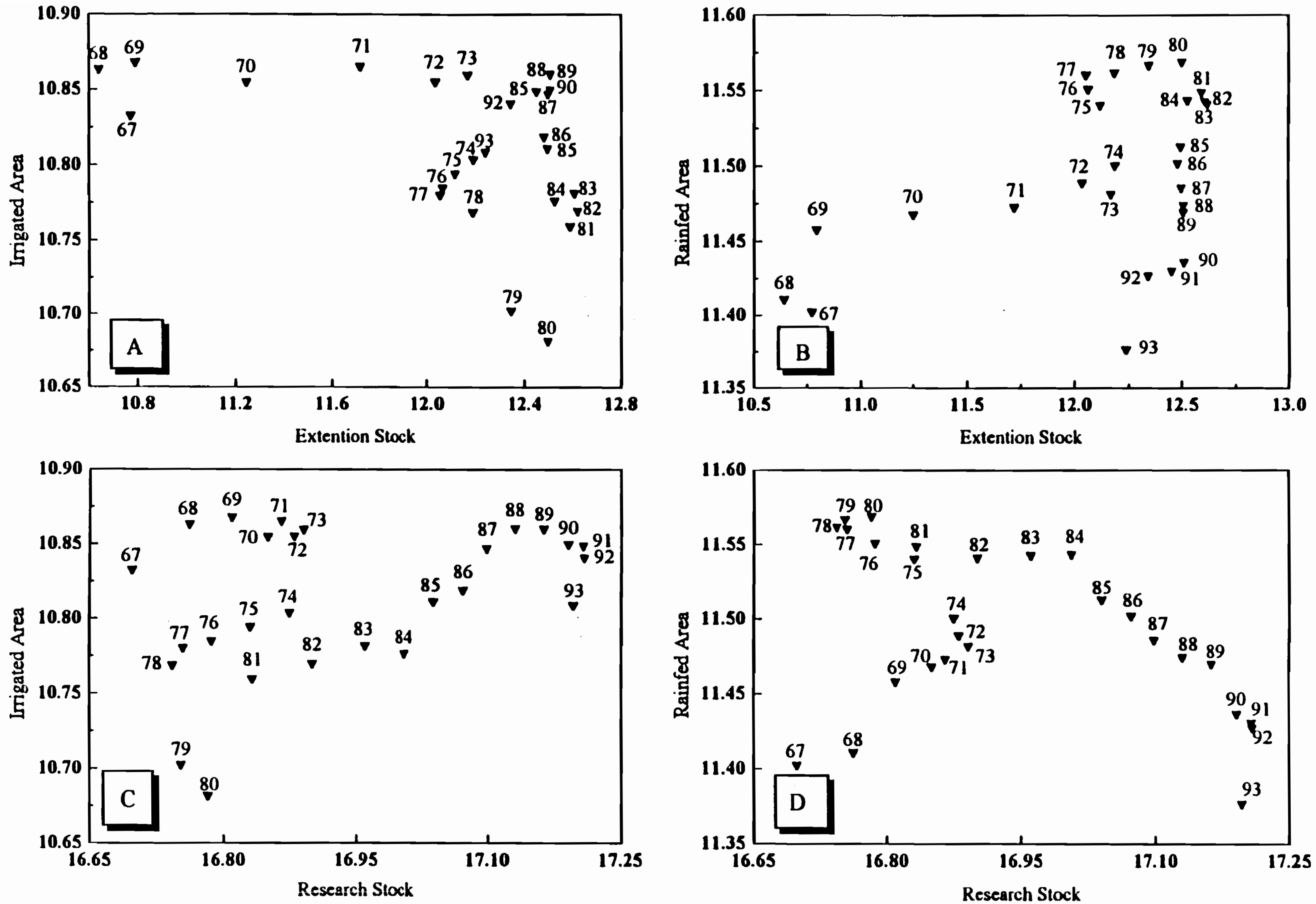

Fig. 5-2. Relationship between total rice area ('000 ha) in the wet zone and the extention and research stock variables (all variables are in logs).

total area and rice prices in the dry zone presented in Figure 5-1 illustrate this fact. The relationship between rice area and technology stocks was different for the period before 1973 compared to the period after 1973 (Figures 5.1 and 5.2). The data set covering the period 1968-1973 was too short to conduct tests for possible structural change in or around 1973. Therefore, it was decided to limit the analysis to the period 1974-1993, with necessary corrections to filter out effects of changes in government policies.

The total irrigated rice area in the wet zone displayed a declining trend during the 1970s. The trend was reversed in the 1980s and the total irrigated area in the wet zone returned to early-1970 level by 1988. Since then, irrigated area in the wet zone has been declining. A small percentage of the irrigation development funds are spent by the government in the wet zone. Therefore, it was decided to limit the analysis of effects of irrigation development expenditures only to the dry region.

Table 5-1 presents the range, mean, and standard deviation for the variables for the period 1974-1993. The summary statistics show that the variation in the dependant variables, particularly in area variables, is relatively low except in the irrigated dry zone. The total irrigated area in the dry zone continued to grow over the full duration analyzed while areas in the rainfed dry zone and the wet zone either stagnated or

Table 5-1. Description of Variables and Data

Variable	Units	Minimum	Maximum	Mean	Std. Deviation	Coefficient of Variation
TAIW	(ha.)	43549	52081	49229	2398	0.05
TARW	(ha.)	87270	105760	99372	5214	0.05
TAID	(ha.)	299048	446240	381451	48258	0.13
TARD	(ha.)	132510	154798	148550	5789	0.04
AIWM	(ha.)	40149	47645	45870	1691	0.04
ARWM	(ha.)	78611	97974	89200	6099	0.07
AIDM	(ha.)	188343	341259	290560	42843	0.15
ARDM	(ha.)	75358	131879	108086	17261	0.16
AIWY	(ha.)	27442	42321	36191	3671	0.10
ARWY	(ha.)	44059	91925	75021	12421	0.17
AIDY	(ha.)	92873	236584	148110	33486	0.23
ARDY	(ha.)	13057	29448	23681	3733	0.16
ACDM	(ha.)	30690	85440	70220	13287	0.19
ACDY	(ha.)	22040	37980	29436	4771	0.16
YIWM	(Tons/ha.)	2.47	3.47	3.08	0.31	0.10
YRWM	(Tons/ha.)	1.77	2.96	2.47	0.43	0.18
YIDM	(Tons/ha.)	2.63	4.14	3.46	0.51	0.15
YRDM	(Tons/ha.)	1.93	3.01	2.53	0.38	0.15
YIWY	(Tons/ha.)	2.24	3.27	2.81	0.31	0.11
YRWY	(Tons/ha.)	1.44	2.58	2.15	0.32	0.15
YIDY	(Tons/ha.)	2.14	4.06	3.27	0.61	0.19
YRDY	(Tons/ha.)	1.55	3.57	2.60	0.59	0.23
YCDM	(Index)	0.98	3.20	1.97	0.89	0.45
YCDY	(Index)	0.92	3.66	2.00	1.06	0.53

Contd.

RIWM	(Rs./ha)	3787	15463	6171	2958	0.48
RRWM	(Rs./ha)	2286	9899	4004	1896	0.47
RIDM	(Rs./ha)	3055	9987	5777	2029	0.35
RRDM	(Rs./ha)	1207	6909	3294	1653	0.50
RIWY	(Rs./ha)	3158	13083	5331	2373	0.45
RRWY	(Rs./ha)	1148	8157	2872	1642	0.57
RIDY	(Rs./ha)	3151	9950	5446	1758	0.32
RRDY	(Rs./ha)	1336	8154	3793	1730	0.46
RCDM2	(Index)	238	1046	527	244	0.46
RCDY2	(Index)	351	2610	1071	535	0.50
PPPWM	(Rs./Ton)	710	8297	3717	2277	0.61
PPPWY	(Rs./Ton)	727	8320	3652	2235	0.61
PPPDM	(Rs./Ton)	693	7793	3561	2200	0.62
PPPDY	(Rs./Ton)	703	7943	3530	2130	0.60
PFTM	(Rs./Ton)	369	10300	3049	2770	0.91
PFTY	(Rs./Ton)	369	9850	3327	3046	0.92
IRGN	(log Rs. Mill)	9.68	10.38	10.08	0.28	0.03
RES	(log Rs.)	16.72	17.09	16.88	0.13	0.01
EXTW	(log Rs.)	12.03	12.62	12.36	0.20	0.02
EXTD	(log Rs.)	11.07	11.63	11.37	0.15	0.01
FOODEX	(Rs. Mill.)	780	8449	3497	2010	0.57
RF1WM	(mm)	400	841	587	140	0.24
RF2WM	(mm)	115	603	264	109	0.41
RF1DM	(mm)	194	574	321	90	0.28
RF2DM	(mm)	184	727	350	131	0.38
RF1WY	(mm)	145	630	398	121	0.30
RF2WY	(mm)	193	573	339	114	0.34
RF1DY	(mm)	55	402	205	73	0.36
RF2DY	(mm)	16	205	109	50	0.46

declined following initial increases. Also, the growth in rice yields in all regions slowed down considerably since the early 1980s.

Misspecification Tests

The equations identified in the model outlined in chapter three were subjected to a series of tests to assess the statistical validity of the model equations as specified. Statistically misspecified models may yield biased and inconsistent parameter estimates with the result that hypothesis testing is invalidated. Therefore, pursuing statistical adequacy of the equations is a precondition for accurate estimation of a model's parameters. In practice, misspecification tests are used first to ensure that the estimated equations represent a well-defined statistical-generating mechanism (Spanos, 1986). This ensurance is necessary because customary specification tests such as tests for significance of coefficients, which are based on the validity of the assumptions underlying the statistical model, may not be accurate if the equations themselves are not correctly specified first.

The most general description of the statistical information contained in a data set is provided by the *Haavelmo* distribution (Spanos, 1986). The *Haavelmo* distribution framework is employed in applied econometrics to obtain a statistically adequate model consistent with economic theory. Consideration of statistical adequacy in the context of a reduction from the *Haavelmo* distribution provides a systematic procedure that links the information contained in a data set and assumptions of the regression model.

A complete range of tests to assess statistical adequacy of estimated equations is suggested (Spanos, 1986, McGuirk, Driscoll, and Alwang, 1993). They provide a systematic procedure for conducting misspecification tests in models with equation systems. Accordingly diagnostic tests were implemented on an equation-by-equation basis with the cross-interactions among equations in the system represented by the residuals. Misspecification tests were conducted to assess normality, homoskedasticity and temporal independence. Appropriate respecifications were undertaken until statistically valid equations were obtained. The tests conducted on the equations finally specified and the results are detailed in Appendix B.

The expression of variables in their natural logarithms limited the occurrence of violation of the homoskedasticity assumption. The total area equations under rainfed conditions in the wet and dry zones presented difficulties in satisfying the homoskedasticity assumption. All estimated equations were free of serial correlation. Satisfying the normality assumption in the area and yield equations required inclusion of several dummy variables over the ones described in chapter four to obtain an adequate model. These dummy variables corresponded to seasons that experienced serious disruptions in the normal production pattern due to heightening of civil unrest in the dry zone areas from late 1980s and the physical breakdown of irrigation systems in the wet zone. Thus, these dummy variables are expected to have negative signs associated with them.

Econometric Estimates

Estimation results are presented in this section. The block of quasi-fixed input equations contain four total rice area equations that were estimated as a system. The area and yield equations were estimated in four blocks, each representing the wet or dry region crops during either the maha or yala season. The wet-zone equation block contains two equations and the dry-zone block three equations in each season.

Parameters were estimated using the Iterative-Seemingly Unrelated Regression (ITSUR) procedure (Kmenta, 1986). The Gauss-Newton method was used to minimize the objective function with the convergence criteria set at 0.001 (SAS/ETS, 1992). The SAS/ETS non-linear modeling system, MODEL procedure was used.

Significance tests that involve multiple hypotheses should be carried out with the nominal level of significance properly adjusted to reflect the change in actual critical value. Corrections based on Scheffe, Bonferroni, and Sidak approximations are suggested (McGuirk, Driscoll, and Alwang, 1993). However, the selection between these alternatives is not straightforward. Scheffe is an infinite induced test that assumes all linear combinations of hypotheses tested are of equal interest, which is seldom true. Thus, in a regression equation with 5 regressors, for tests conducted with an α level of 0.05 the relevant critical value for the Scheffe test is 3.32. Bonferroni and Sidak are finite induced tests that are free of the above deficiency in the Scheffe test. When the Bonferroni procedure is used with 5 tests to maintain a significance level of 0.05 (critical t value of 1.64), the tests have to be actually carried out assuming a significance level of 0.01 (critical t value 2.32). The Bonferroni test is considered more conservative than it has to be. However, the calculation of correct critical values under the finite tests is complicated due to the difficulty in knowing the exact sampling distribution of the test statistic. The Scheffe test has more power than finite induced tests in the presence of multicollinear data. Thus, instead of adjusting the nominal test size directly assuming any of the above test procedures, standard errors of coefficients are reported, and the discussion of parameters is focussed on those estimates at least twice as large as the standard errors which corresponds to a 5% significance level.

Quasi-fixed Input Equations

Estimation results for the quasi-fixed input equations block are shown in Table 5-2. The quasi-fixed input equations in each region consist of total (asweddumized) rice areas under irrigated and rainfed categories. The determination of the four asweddumized area equations is explained by expected changes in profitability of similar land developed for rice, exogenous government investments in irrigation, rice research, and extension represented by their stocks, and by variables representing economic and policy environment. The changes in economic and policy outlook are represented by two variables: lagged annual expenditure on the importation of rice and wheat flour, and the dummy variable (**D7477**) representing the relevant portion of the 'import-substitution policy regime' in effect during 1970-1977. A second dummy variable (**D7980**) was included in the wet zone area equations to account for the temporary drop in the irrigated rice area during 1979-80 due to an irrigation system breakdown. The changes in the irrigated rice areas are explained better than the changes in the rainfed rice areas (Table 5-2).

In the wet zone, increases in the expected profitability of new irrigated rice area ($\mathbf{RPROF}_{ij}$) show the expected positive influence on the growth of total rainfed rice area, but are insignificant in the irrigated area equation. In the dry zone, positive revenue expectations exerted a strong positive influence on the growth of both rainfed

Table 5-2. Estimated Parameters for the Block of Total (Asweddumized) Rice Area Equations [a/]

	Wet Zone		Dry Zone	
	Irrigated Rice	Rainfed Rice	Irrigated Rice	Rainfed Rice
Constant	**3.363**	**16.593**	**7.131**	**12.346**
	(0.812)	(1.444)	(1.115)	(1.276)
Expected Revenue	0.031	**0.096**	**0.058**	**0.064**
	(0.021)	(0.041)	(0.025)	(0.029)
Irrigation Stock	-	-	**0.241**	**0.101**
	-	-	(0.027)	(0.030)
Research Stock	**0.372**	**-0.376**	**0.200**	-0.105
	(0.037)	(0.071)	(0.058)	(0.067)
Extension Stock	**0.091**	0.047	**-0.062**	-0.005
	(0.027)	(0.052)	(0.031)	(0.036)
Lagged Food Expend.	**-0.036**	-0.028	0.008	**-0.027**
	(0.011)	(0.022)	(0.011)	(0.014)
Dummy '7477	0.017	-0.035	**-0.074**	**-0.047**
	(0.016)	(0.031)	(0.015)	(0.020)
Dummy '7980	**-0.068**	0.024	-	-
	(0.007)	(0.012)	-	-
SSE	0.002	0.008	0.002	0.003
Adj. R^2	0.94	0.81	0.99	0.69
D.W.	1.31	0.97	1.74	1.44

[a/] Figures in parenthesis are standard errors, and
the coefficients shown in bold face have 't' values greater than 2.

and irrigated rice areas. The effect of expected revenue on the rainfed and irrigated area growth in the dry zone is nearly equal.

The effect of irrigation on total rice area in the dry zone is positive and strongly significant in the both rainfed and irrigated area equations. The research stock variable has significant yet opposite signs in the two wet zone area equations. The inverse relationship between the research stock and rainfed area is counter intuitive, particularly in the wet zone where the risks of crop failure are less severe. The research stock had a positive significant influence on the total irrigated rice area in the dry zone, but did not affect the rainfed area significantly. Given the well- known bias of new rice varieties to perform best under favorable cultivation conditions, the latter observation is not surprising under the high-risk conditions existing in the rainfed dry zone.

The extension variable had a positive significant effect on the total irrigated rice area in the wet zone, but a negative effect in the dry zone. The latter effect lacks any rationale and is likely to be caused by a spurious correlation. Extension had no effect on the rainfed rice areas. Lagged food expenditures had a negative significant effect on irrigated wet zone and rainfed dry zone rice areas. This variable has a depressing effect on area growth as greater imports of rice and wheat flour dampen prospects for receiving higher future returns from domestic rice.

Government policies during 1970-1977 period, captured in D7477, had significantly negative effects on the dry zone rice area, but did not affect the wet zone area significantly. The economic policies of the 1970-1977 government were based on an import substitution strategy that introduced severe economy-wide controls on land and property ownership, land reforms, ceilings on income, etc. (Athukorala and Jayasuriya, 1994). Stringent quantitative controls on imports which included intermediate-inputs such as fertilizers and farm machinery were necessitated by sharp declines in terms of trade and pressures on the balance of payments. The economic climate was not congenial to private investments. The decline captured by the dummy variable reflects the influence of these adverse investment-impacts on the rice sector.

The results of quasi-fixed input equations show the key role of economic incentives and technology-related public-investment variables on the decisions to expand area allocated to rice production. In the dry zone, where the commercial orientation of rice production is strong, farmers responded strongly to higher potential earnings. Irrigation and research investments also favored bringing more land into rice production in the dry zone.

Planted Area Equations

The area equations describe how the composition of techniques adopted in the wet and dry regions during maha and yala seasons respond to incentives, constraints and environments. The incentives are represented by the expected revenue for the appropriate category of land and the season. The variables representing the expected revenues of alternative techniques were dropped from the estimated planted area equations as the high correlation between these revenue variables caused difficulties for parameter estimation. Several dummy variables that are explained below were included to account for the planting disruptions due to events such as the civil war that are not captured by the other variables.

Maha Season:

Table 5-3 presents estimation results for the maha planted area equations. The area planted in the wet zone was not influenced by revenue expectations (**RIWM** and **RRWM**). The results presented used one-season lagged prices, yields, and costs to formulate expected net revenues. However, several alternative formulations of gross and net revenue expectations that approximated expected yields by moving averages and logarithmic trends were tried in the estimation. All different revenue formulations provided markedly similar results. The price of cash crops (**PCASH**) was

Table 5-3. Estimated Parameters for the Block of Planted Area Equations [a/] - Maha Season

	Wet Zone		Dry Zone		
	Irrigated Rice	Rainfed Rice	Irrigated Rice	Rainfed Rice	Cash Crop
Constant	**2.648**	-1.820	-5.976	**21.819**	9.198
	(1.079)	(1.087)	(4.156)	(7.928)	(5.962)
Expected Rev.-Rice	0.009	0.021	-0.063	0.023	0.119
	(0.012)	(0.013)	(0.050)	(0.031)	(0.089)
Cash Crop Price	-	-	-0.033	-0.094	0.024
	-	-	(0.053)	(0.048)	(0.048)
Total Area	**0.737**	**1.137**	**1.391**	-0.903	0.095
	(0.094)	(0.096)	(0.307)	(0.653)	(0.569)
Pre-plant Rainfall	0.008	-0.006	**0.263**	**0.181**	-0.031
	(0.024)	(0.028)	(0.090)	(0.070)	(0.092)
Dummy 8693	-	-	**-0.210**	**-0.315**	0.023
	-	-	(0.070)	(0.034)	(0.070)
SSE	0.007	0.010	0.117	0.072	0.123
Adj. R^2	0.72	0.88	0.66	0.83	0.34
D.W.	1.61	0.67	1.76	2.65	1.94

[a/] Figures in parenthesis are standard errors, and
the coefficients shown in bold face have 't' values greater than 2.

neither a significant determinant of its own area nor the rice area in the dry zone. The lack of a price responsiveness by Sri Lankan rice production was observed before in the study by Bogahawatte (1983) for the period 1955 to 1979. In that study, only the area planted in dry region during maha season out of four area categories examined showed a significant price response.

In the wet zone, the planted area under irrigated and rainfed rice are explained mostly by the total rice area (**TAIW** or **TARW**). Total area is the key variable explaining the planted area of irrigated rice in the dry zone. In the dry zone, total area does not help in explaining the area planted to rice or the cash crops that are cultivated under rainfed conditions. The cultivation of rainfed crops in the dry zone depends heavily on the seasonal rainfall, and may lead to this situation. The pre-planting rainfall during the maha season (**RF1WM**) was not a significant determinant of the area planted in the wet zone. In general, the rainfall during the maha season is not observed to limit planting in the wet zone. In the dry zone, the rice area planted in the maha season is favorably influenced by the pre-planting rainfall (**RF1DM**). Higher pre-planting rainfall stimulates a higher area response in the irrigated areas as well. In the minor irrigation areas, the small reservoirs depend more on the monsoon rains to stock up irrigation water than the stream-fed large reservoirs. The decline in the area planted in the dry zone captured in the dummy variable, **D8693**, represents the period most adversely affecting agriculture activities in the northern Sri Lanka due to civil disturbances.

The dry zone is the net-surplus rice production area in the country and is considered to have a greater commercial orientation in production than in the wet zone. However, the results fail to capture any discernible short-run response to price or revenue incentives. The total rice area was the key determinant of the planted area and showed a significant positive response to increased revenue expectations. The results from the estimation of maha season area equations suggest that the inter-technique effects are mostly driven by the changes in the levels of quasi-fixed inputs. Increasing the area developed for rice cultivation seems to generate greater planted acreage in the maha season except in the rainfed dry zone. The short-run area response to incentives was not significant in either region.

Yala Season:

Results of area estimation for the yala season presented in Table 5-4 are not substantially different from those reported for the maha season. The estimated equations explain most of the variation in rice plantings during yala, but only a small portion of the variation in cash crop area determination. Area planted to rice in yala in the wet zone was not influenced by the expected revenues. In the dry zone, the area

Table 5-4. Estimated Parameters for the Block of Planted Area Equations [a/] - Yala Season

	Wet Zone		Dry Zone		
	Irrigated Rice	Rainfed Rice	Irrigated Rice	Rainfed Rice	Cash Crop
Constant	**-6.696**	1.048	**-4.679**	0.587	-7.479
	(2.392)	(2.688)	(0.587)	(2.646)	(5.667)
Expected Rev.-Rice	0.003	0.047	0.054	**0.187**	**-0.246**
	(0.031)	(0.043)	(0.187)	(0.075)	(0.115)
Cash Crop Price	-	-	0.065	0.127	-0.031
	-	-	(0.127)	(0.067)	(0.068)
Area Planted-Maha	**1.476**	**0.626**	**1.178**	**0.518**	**1.875**
	(0.220)	(0.255)	(0.518)	(0.222)	(0.600)
Pre-plant Rainfall	**0.223**	**0.446**	0.162	**0.205**	0.065
	(0.032)	(0.051)	(0.205)	(0.073)	(0.079)
SSE	0.035	0.089	0.269	0.253	0.300
Adj. R^2	0.80	0.85	0.59	0.50	0.23
D.W.	1.67	1.53	2.16	2.39	1.53

[a/] Figures in parenthesis are standard errors, and
the coefficients shown in bold face have 't' values greater than 2.

planted to rainfed rice responded positively to expected revenue increases, but not the irrigated rice. The price of cash crops neither influenced the area planted to rice nor cash crops. However, higher revenue prospects for rice in yala reduces area planted to cash crops. As cash crops in yala are mostly planted in irrigable rice fields, the trade-off in revenue potentials between the two crops would affect planting decisions.

The cultivation of a rice field during the maha season makes that field relatively less expensive to plant in the yala season since some initial land preparation was completed during maha season making it feasible to get the land ready for planting within the short inter-season fallow period. The rice areas planted in the yala season both in the wet and dry regions are explained by the area planted in the previous maha season which is highly significant in all equations. In the case of cash crops, area planted in the previous yala season was the only variable increasing the area planted in the current season.

Pre-planting rainfall received in the yala season (**RF1WY** and **RF1DY**) was strongly significant in explaining rice area planted in both wet and dry regions. In general, low incidence of rainfall during yala severely limits planted area. By facilitating early land preparation everywhere, even in the areas under irrigation development, pre-planting rainfall strongly influences rice planting. The rainfall during this period had little influence on the area of cash crops which were mostly grown under irrigated conditions.

Area allocation decisions in the dry zone during yala are not as well explained as those during the maha season. The area planted in the dry zone during yala declines to less than 50 percent of the total area under irrigation and to less than 20 percent in the rainfed areas. This decline is attributed to the shortage of seasonal rainfall and inadequate storage left in the reservoirs feeding irrigated rice areas following the completion of the major season crop.

Estimation results of area equations for the maha and yala seasons indicate that the level of impacts of the total rice area, the primary quasi-fixed input, and incentives on the area allocation decisions are modified by the fixed district and seasonal effects. The treatment of techniques by their regional and seasonal variation helps better explain components of area determination. In the maha season, the levels of quasi-fixed inputs have very significant intertechnique effects. These influences remain strong in yala as well, but are influenced more by seasonal effects than in maha season.

The most important observation pertaining to planted-area response is the absence of a significant price response beyond the levels observed at the total area determination stage. A significant response to increased revenue expectations was observed in three out of four total area determination equations examined for rice. Once the total area available for planting was determined, the actual area planted is largely determined by seasonal weather. Given the relatively high cost associated with initial land development for rice cultivation, once this initial investment is made, short-run fluctuations in prices and revenues may not have a great impact on the planting decision which is primarily affected by the physical factors of the production environment.

Yield Equations

Parameter estimates for blocks of yield equations estimated for the maha season are shown in Table 5-5, and for the yala season in Table 5-6. The four yield blocks correspond to the classification used for area equations and are discussed below in the same order. The yields are explained by prices of outputs and inputs, quasi-fixed inputs, and the environment represented by rainfall during the first two months of the growing season.

Maha Season:

Maha equations explain the yield variation reasonably well for the wet and dry regions. The price of rice had no influence on rice yields in the wet zone or the dry zone (Table 5-5). The price of fertilizer, the only input price examined, did not influence maha rice yields except in the rainfed wet zone, in which equation it suggested the existence of a positive effect that is contrary to usual expectations. The absence of a clear response to fertilizer price is likely caused by interference by successive governments to keep the market price of fertilizer unchanged under various subsidy schemes. The price of cash crops has the wrong sign in the maha cash-crop yield determination equation.

Irrigation stock, **IRGN**, had a positive and significant influence on the dry zone rice and cash crop yields during maha season. Improved efficiency in the supply of irrigation water, reflected in increasing irrigation stocks, favorably influenced rice yields in the dry zone during maha season even with the higher rainfall received in that season relative to the yala season.

Stocks of rice research expenditures, **RES**, had a strong positive influence on wet zone rice yields while the effect on the dry zone rice yields was not significant. However,

Table 5-5. Estimated Parameters for the Block of Yield Equations [a/] - Maha Season

	Wet Zone		Dry Zone		
	Irrigated Rice	Rainfed Rice	Irrigated Rice	Rainfed Rice	Cash Crop
Constant	**-8.891**	**-22.407**	-9.789	-8.306	**-32.821**
	(3.156)	(3.037)	(8.598)	(9.735)	(14.124)
Rice - Cash Crop Price	-0.046	0.043	0.136	0.126	-0.225
	(0.080)	(0.077)	(0.093)	(0.108)	(0.132)
Fertilizer Price	-0.007	**0.076**	0.040	0.042	0.011
	(0.037)	(0.035)	(0.047)	(0.053)	(0.088)
Irrigation Stock	-	-	**0.469**	**0.526**	**0.873**
	-	-	(0.168)	(0.189)	(0.390)
Research Stock	**0.402**	**0.757**	0.186	0.106	**1.715**
	(0.120)	(0.116)	(0.409)	(0.460)	(0.780)
Extension Stocks	**0.286**	**0.773**	0.192	0.118	-0.344
	(0.109)	(0.105)	(0.252)	(0.285)	(0.461)
Post-plant Rainfall	0.022	0.003	-0.073	-0.094	0.142
	(0.034)	(0.033)	(0.043)	0.048	(0.083)
SSE	0.043	0.040	0.048	0.061	0.170
Adj. R^2	0.70	0.91	0.80	0.78	0.94
D.W.	1.50	1.57	2.00	2.49	1.58

[a/] Figures in parenthesis are standard errors, and the coefficients shown in bold face have 't' values greater than 2.

cash crop yield was positively influenced by the rice research expenditures suggesting positive spill-overs. In general, the impact of extension expenditures, **EXTW** and **EXTD**, on the yield of rice appeared to be beneficial in both regions but were significant only in the wet zone. The impact of immediate post-planting rainfall in the wet zone (**RF2WM**) or the dry zone (**RF2DM**) rice yields were not significant.

Research and extension stocks, the technology-related government-investment variables strongly influenced wet zone rice yields in the maha season. In the dry zone, all three technology variables including irrigation had a positive influence, but only the effects of irrigation were significant at 5% level. The development and dissemination of new rice technology has been most successful when the complete package of irrigated lands, high-yielding varieties, and improved technologies such as fertilizer application and pest management practices were combined. The three government-investment variables in the dry zone account for key elements of this strategy. While lack of their statistical significance weakens the usefulness of the results, they all jointly suggest movement in the expected direction.

Estimation results for maha yield equations are encouraging, but fall short of confirming key relationships affecting yield. In the dry zone where the risk of crop failures from water shortage are high, the strongest response was observed with respect to irrigation stocks. The results reiterate the critical importance of irrigation development in expanding rice output from the dry zone in Sri Lanka.

Yala Season:

Yala yield equations presented in Table 5-6 indicate much variability across the wet and dry zones. As noted earlier, the portion of total area planted during yala in the dry zone declines sharply from maha due to lack of rainfall and irrigation water. Rice producers in the dry zone may be less responsive during yala to various price and technology initiatives due to greater rainfall uncertainty.

The yields during yala are not much influenced by the expected prices of outputs or fertilizer. In the wet zone, irrigated rice yields had the wrong sign with respect to the price of rice (**PRICEWY**) while rainfed rice responded negatively to increases in fertilizer price (**PFERTY**). The same equation had the wrong sign on fertilizer in the maha season. The yield response to price variables in the dry zone were insignificant as in maha, and most had the wrong sign.

Irrigation stocks, **IRGN**, had a significant positive yield impact on both irrigated and rainfed rice in the dry zone. Irrigation expenditure favorably impacts the yield of cash crops which are cultivated under irrigation during the yala season. Research stocks

Table 5-6. Estimated Parameters for the Block of Yield Equations [a/] - Yala Season

	Wet Zone		Dry Zone		
	Irrigated Rice	Rainfed Rice	Irrigated Rice	Rainfed Rice	Cash Crop
Constant	**-6.544**	-20.094	10.006	10.953	-15.216
	(2.948)	(0.081)	(8.584)	(16.120)	(26.653)
Rice - Cash Crop Price	**-0.164**	0.161	-0.192	-0.318	-0.034
	(0.032)	(0.103)	(0.100)	(0.254)	(0.126)
Fertilizer Price	0.009	**-0.127**	0.085	0.097	-0.160
	(0.089)	(0.033)	(0.062)	(0.116)	(0.195)
Irrigation Stock	-	-	**0.806**	**0.800**	**1.849**
	-	-	(0.206)	(0.388)	(0.650)
Research Stock	**0.213**	**0.737**	**-0.906**	-1.178	0.471
	(0.103)	(0.152)	(0.449)	(0.825)	(1.484)
Extension Stocks	**0.398**	**0.633**	-0.072	0.286	-0.792
	(0.059)	(0.192)	(0.250)	(0.459)	(0.813)
Post-plant Rainfall	0.054	0.045	0.012	0.075	-0.083
	(0.166)	(0.061)	(0.032)	(0.059)	(0.103)
SSE	0.026	0.089	0.072	0.242	0.729
Adj. R^2	0.86	0.75	0.82	0.66	0.82
D.W.	1.70	2.39	1.28	1.92	1.31

[a/] Figures in parenthesis are standard errors, and
the coefficients shown in bold face have 't' values greater than 2.

(**RES**) positively influenced rice yields in the wet zone. The positive impacts of research on wet zone rice yields observed in the maha season are reinforced by the yala results. The effect of research stocks on irrigated-yala rice yields was negative in the dry zone. This is not consistent with expectations. The extension stock variable in the wet zone (**EXTW**) strongly and positively influenced yala rice yields too, but in the dry zone the impact of extension stocks (**EXTD**) was not significant for any crop. The effects of environment represented by the rainfall after planting are not significant in either region.

The results from the estimation of yield equations suggest that the technology variables and the level of quasi-fixed inputs largely determined rice yields. The area estimation results indicate that the implemented techniques were strongly influenced by the levels of quasi-fixed inputs. Thus, the overall impact of the quasi-fixed inputs on the growth of total rice output is illustrated by the area and yield estimation results. The suggested lack of favorable impact of rice research on yala season rice yields in the dry zone may be explained when the observed uncertainty in rice cultivation during that season is weighed against the bias in new rice varieties toward producing the best results under optimum growing conditions. These new rice varieties have fully replaced more drought and pest resistant but low yielding traditional rice varieties. The best means to assure increased rice production from the dry zone seems to rest largely on the ability to provide sufficient irrigation capability. In the wet zone, where the cultivation conditions are less challenging for crop growth, research and extension efforts yielded strong yield benefits.

Elasticity Estimates

Estimates of area and output elasticities are presented and discussed below. Short run and long run elasticities are often calculated with this type of models. The short-run elasticities assume the levels of quasi-fixed inputs are fixed at the sample values. As the dependent and independent variables were expressed in their logarithms, the short-run area and yield elasticities with respect to the relevant variables are given by the estimated coefficients in the respective equations. The elasticity of area with respect to price is derived from the coefficient of the revenue variable in the area equation using the relations:

$$(5.1) \qquad \frac{\partial A}{\partial P} \cdot \frac{P}{A} = \left(\frac{\partial A}{\partial \Pi} \cdot \frac{\Pi}{A}\right)\left(\frac{\partial \Pi}{\partial P} \cdot \frac{P}{\Pi}\right) = \left(\frac{\partial A}{\partial \Pi} \cdot \frac{\Pi}{A}\right)\left(Y \cdot \frac{P}{\Pi}\right).$$

in which the first term is the required elasticity, and the term to the right of the second equal sign is the estimated coefficient of the revenue variable. The values of yield (Y), price (P), and profits (Π) are evaluated at their mean values. As the yields are averaged by technique, area elasticities with respect to price and yield are identical because the profit (Π) is defined as expected price times yield less costs. When the profit is approximated by the gross revenue (price times yield) as in the total area equations, the price elasticity of area is equal to the coefficient of the revenue term.

As the coefficients of the revenue variable in all planted area equations were statistically insignificant, short-run area elasticities from the estimated planted area equations for the two seasons were not computed. The long-run elasticity of planted area with respect to the price of rice and other variables are computed by combining coefficients of the revenue and total area variables in the total area and planted area equations respectively. It can be shown that the elasticity of planted area with respect to price ($\epsilon_{Ap, P}$) can be derived from the elasticities of total area with respect to price ($\epsilon_{AT, P}$) and the planted area with respect to the total area ($\epsilon_{Ap, AT}$) as follows:

$$(5.2) \qquad \varepsilon_{AP,P} = \frac{\partial A_P}{\partial P} \cdot \frac{P}{A_P} = \left(\frac{\partial A_P}{\partial A_T} \cdot \frac{\partial A_T}{\partial P} \right) \left(\frac{P}{A_P} \right),$$

$$(5.3) \qquad \varepsilon_{AP,P} = (\varepsilon_{AP,AT}) \cdot \frac{A_P}{A_T} \cdot (\varepsilon_{AT,P}) \cdot \frac{A_T}{P} \cdot \frac{P}{A_P},$$

$$(5.4) \qquad \varepsilon_{AP,P} = (\varepsilon_{AP,AT}) \cdot (\varepsilon_{AT,P}).$$

A parallel procedure can be used to derive planted area elasticities with respect to other technology related variables such as irrigation, research and extension stocks. Short-run yield elasticities are directly obtained from the coefficients of the yield determination equations.

The long-run output elasticities can be calculated by dynamic simulation of the full model. The model is first simulated with all the exogenous variables fixed at their original levels to obtain the baseline results. Then the model is simulated again with the level of the variable for which the elasticity is needed increased by one percent. The average change in the annual rice output over the sample period is treated as elasticities.

The total area elasticities with respect to technology variables are greater than the price elasticities (Table 5-2). The total area in the wet and dry regions responded similarly to price. Both irrigated and rainfed areas in the dry zone responded strongly to irrigation investments as shown by the high elasticities relative to price elasticities. Irrigated total rice area responded very favorably to research in both regions. The elasticity of total area with respect to extension was weak relative to the response to research or irrigation.

Estimated rice planted area elasticities are shown in the Table 5-7. Rice area elasticities with respect to own price are positive in the rainfed wet-zone rice and irrigated dry-zone rice. The own-price area elasticities range between 0.07-0.11indicating an inelastic response by the rice producers. The spatial and temporal variations in area response cannot be fully examined as only half of the elasticity estimates are obtained from statistically significant coefficients. The area response to

Table 5-7. Rice Area Elasticities - Long Run

	Elasticities			
	Rice Price	Irrigation	Research	Extension
<u>Maha Season</u>				
Wet Zone:				
Irrigated Rice	0.02	-	0.27*	0.07*
Rainfed Rice	0.11*	-	-0.43*	0.05
Dry Zone:				
Irrigated Rice	0.08*	0.34*	0.28*	-0.09*
Rainfed Rice	-0.06	- 0.09	0.09	0.01
<u>Yala Season</u>				
Wet Zone:				
Irrigated Rice	0.04	-	0.40*	0.10*
Rainfed Rice	0.07*	-	-0.27*	0.03
Dry Zone:				
Irrigated Rice	0.10*	0.39*	0.33*	-0.10
Rainfed Rice	-0.06	0.05	0.01	0.01

* Denotes elasticities derived from statistically significant coefficients

price in the dry region appears to be slightly higher than that of the wet zone. The differences between the irrigated and rainfed rice are negligible. Rice area planted in yala season was expected to be more responsive to incentives. In the maha season, the available choices are limited to planting rice or fallowing as the cultivation of non-rice crops is infeasible due to excessive wetness. In the yala season, some of the rice lands in the lower elevations become sufficiently dry to plant non-rice crops. Also, the ability to meet own consumption needs from the major-season rice crop in maha allows more flexibility in the yala-crop choice. The observed elasticities do not provide any support in favor of the above supposition of higher price responsiveness during yala. The direct or cross price elasticities with respect to the weighted index of cash crop prices were not significant in either season and therefore excluded from the analysis.

The rice area elasticities reported above are comparable to the estimates reported for Sri Lanka in previous studies. In a study covering the period 1955-1979, Bogahawatte (1983) reported a short-run area elasticity of 0.13 for the maha season in the dry zone which was the only significant estimate. The ratio of the government's guaranteed price for rice (GPS) and the weighted average price for cash-crops was used as the price variable. Gunawardana and Oczkowski (1992) reported that, for the period between 1952-1987, rice area was not responsive to the price specified as the ratio of the guaranteed price to fertilizer price. The use of GPS price which lagged behind the open-market price for rice casts some doubt on the validity of their results.

The area elasticity estimates reported above are within the range of those reported by Askari and Cummings (1977). Hennebery (1986) summarized the estimates of supply elasticities for rice for a number of developing countries in Asia. Most of the studies were for periods prior to 1980, and reported price elasticities less than 0.2. The comparison of estimates from various studies is difficult due to differences in model specification, and estimation procedures. In general duality methods gave the largest short-run elasticity estimates for rice. Also, rice area elasticities were in general the smallest among field crops. In their study that employed the choice of technique framework, McGuirk and Mundlak, (1991) obtained short-run rice area elasticities with respect to price between 0.19 for the modern variety rice and 0.26 for the dry rice, for the Indian Punjab for the period 1960-1979. In other studies in Asia, the area response to price for modern variety rice was estimated to range between 0.32-0.40 in Pakistan (Siddiqui and Ahmed, 1993), and around 0.02 in India (Kumar and Rosegrant, 1993).

Area elasticities with respect to irrigation stocks are much larger than price elasticities in the irrigated dry zone (Table 5.7). This shows that the irrigation expansion is the primary means that can be employed to increase rice planting in the dry zone. Area elasticities with respect to research were positive and significant in irrigated rice in both wet and dry regions. In the wet zone, research investments had a negative impact on the rainfed area while in the dry zone the effect was positive but insignificant. Rice area elasticities with respect to extension investments were small but positive in the irrigated wet zone, negative in the irrigated dry zone. In the dry zone, area elasticities with respect to irrigation and research were nearly equal and larger than the response to price. These observations reiterate the strong technology effects on rice production growth in Sri Lanka.

Short-run rice yield elasticities with respect to price and the technology variables are presented in Table 5-8. Own price elasticities of yield were not significant except in the irrigated wet zone in yala where the sign was counter-intuitive. The elasticities with respect to fertilizer prices were not significant except in the rainfed rice crop in the wet zone. The lack of response to fertilizer price was not unexpected, as discussed elsewhere, the price of fertilizer which was controlled under the subsidy scheme, at times remained fixed for several years.

Yield elasticities in the dry zone with respect to irrigation were high in both irrigated and rainfed rice. The elasticities increased considerably from maha season to yala season. As observed before, successful cultivation of yala season rice in the dry zone is heavily dependant on water availability. The availability of irrigation offers a very

Table 5-8. Rice Yield Elasticities - Short Run

	Elasticities				
	Rice Price	Fertilizer Price	Irrigation	Research	Extension
<u>**Maha Season**</u>					
Wet Zone:					
Irrigated Rice	-0.04	-0.01	-	0.40*	0.29*
Rainfed Rice	0.04	0.08	-	0.78*	0.77*
Dry Zone:					
Irrigated Rice	0.14	0.04	0.47*	0.19	0.19
Rainfed Rice	0.13	0.04	0.53*	0.11	0.12
<u>**Yala Season**</u>					
Wet Zone:					
Irrigated Rice	-0.16*	0.01	-	0.21*	0.40*
Rainfed Rice	0.16	-0.13*	-	0.74*	0.63*
Dry Zone:					
Irrigated Rice	-0.19	0.09	0.80*	-0.91	-0.07
Rainfed Rice	-0.32	0.10	0.80*	-1.18	0.29

* Denotes elasticities derived from statistically significant coefficients

high guarantee of success that favors intensive cultivation. Also, the agronomic conditions during yala are more favorable for obtaining high yields when irrigation is not a constraint. However, the high yield elasticity observed in the rainfed rice with respect to irrigation lacks a strong empirical validity other than a (mis)representation of technological effects captured in the irrigation stock variable.

The yield elasticities with respect to research and extension are positive and significant in the wet zone during both seasons. Research and extension elasticities in the rainfed wet zone rice are higher than in the irrigated rice. Yield elasticities with respect to research and extension in the dry zone were mostly insignificant.

Own-price yield elasticities for rice previously reported for Sri Lanka were 0.39-0.48 for the wet zone, and 0.18-0.25 (not statistically significant) for the dry zone (Bogahawatte, 1983). In the study by Gunawardana and Oczkowski (1992), aggregate rice yield elasticity with respect to price was observed to be 0.04 whereas there was no response in area to price.

The most significant observation made from the parameters estimated is the importance of the elasticities associated with the quasi-fixed inputs compared to the price elasticities. The yield response to research expenditures and irrigation are considerably higher than the price elasticities previously reported for Sri Lanka or observed elsewhere in Asia. The price elasticity of output is often observed to be low with staple food crops (Askari and Cummings, 1976; Henneberry and Tweeten, 1991). But, the results presented suggest that effects such as the impacts of technology-related government investments may explain a major share of producer response in some situations.

Policy Simulations

The supply model was used in a simulation to examine the effect of the revealed output trends on the future rice supply-demand balances for Sri Lanka over the period 1995-2005. It was considered that a longer time frame would exceed the predictive ability of this type of model, particularly in view of the fact that estimates of several key variables had poor statistical significance levels.

Several likely scenarios were simulated using the rice supply model with altered values of policy variables. In the baseline simulation, the expected future supply of rice for the period up to 2005 were projected from the model assuming no major deviations from current policies and trends. The results from the baseline simulation were used as the basis for comparison with the results from other scenarios. The alternative scenarios consisted of examining production expansion under increased irrigation expenditure and rice research expenditure.

Procedures and Assumptions

Simulation of values for the endogenous variables was done using Newton's method. A dynamic simultaneous simulation using the Model procedure in the SAS econometric package was used to compute values for endogenous variables in the model (SAS, 1992). The full model was simulated sequentially starting with the equations in the quasi-fixed input block. Solution values of endogenous variables from the previous blocks of equations along with lagged endogenous variables, and other exogenous variables were entered as predetermined variables in the estimation of blocks of area and yield equations. By specifying an alternative set of exogenous variables and initial values of endogenous variables for the extended period, solution values for all endogenous variables of the model were computed. Results were obtained for 20 endogenous area and yield variables disaggregated by regions, seasons and water regimes. The solution values for 16 rice equations were aggregated to obtain total outputs. The total rice output obtained from the base-run simulation and the alternative simulations were compared to derive the policy effects.

The determination of projected exogenous values for individual variables for the 1994-2005 period is discussed below. The stocks of irrigation, research, and extension were computed assuming continuation of trends observed in the most recent years. Irrigation expenditures had started to decline from the late 1980s primarily on account of the decline in new irrigation construction. The prospects for increased investments for new irrigation construction in the future are slim due to small unexploited potential and projected low economic returns to new investments due to declining world prices. However, potential exists for irrigation system rehabilitation and modernization as almost all irrigation projects are inefficient gravity-flow irrigation schemes. As the irrigation schemes already in operation age, there is a need for greater maintenance and operational expenditures. Thus, it was assumed that future irrigation expenditures for new construction would continue to decline at an annual rate of 10 percent while the rehabilitation and operational and maintenance expenditure would grow at 20 percent. This indicated a net one percent annual decline in irrigation expenditures in real terms over the period 1994-2005. Rice research expenditures and extension expenditures of the Department of Agriculture started to increase in the early 1990s following a slow down in the 1980s. They were assumed to maintain an annual two-percent real growth over the period considered.

The prices of rice and fertilizer were assumed to follow the trends indicated for the international market. The most recent projections for primary commodity prices made by the World Bank indicate that the world price of rice in real terms would continue to decline in the foreseeable future (World Bank, 1995). In 1990 constant dollars, the world market price of rice is projected to decline from 243 in 1994 to 241 in year 2000, and 238 in 2005. The price of nitrogenous fertilizers, the major input in rice production is forecast to remain stable at its 1994 level or decrease slightly. With continuing liberalization of the Sri Lankan economy, the prices in the world economy would become increasingly relevant domestically. Agricultural wage was assumed to increase at the expected inflation rate of 10 percent. Thus, expected net returns for the four crops of rice were calculated based on these prices and the predicted yields. The price of cash crops and costs of food import expenditure were expected to remain constant at their most recent real values. The levels of rainfall were set at their mean values for the sample period. Table 5.10 presents the values of the key variables used in the simulations.

Baseline rice requirements for the years 1994-2005 were enumerated from the most plausible scenario suggested by the recent economic and demographic trends. Per capita income projections for Sri Lanka vary widely depending on the source. The annual GDP growth rate for Sri Lanka has shown a high variability in the last 3- 4 years. After considering several sources, a 3 percent annual growth rate in the real income was assumed. Annual population was estimated based on the 'standard' projection of 1.5-1.3 percent annual growth rate for the period used by the Department of Census and Statistics (Sri Lanka, 1994).

Estimates of income elasticities for rice and wheat consumption were taken from previous demand studies for Sri Lanka and other countries in Asia that are similar to

Table 5.9 **Historical Values and Projected Levels of Variables Used in the Simulations - Baseline Projection 1993-2005**

Variable (Units)	Historical	Projected	
	1993	2000	2005
Research (Rs. Mill.)	62	76	88
Extension (Rs. Mill.)	177	218	253
Irrigation (Rs. Mill.)	1932	2076	3751
Rice Price (Rs/ton)	8045	15639	24959
Fertilizer Price (Rs/ton)	9850	19073	30578
GDP Deflator	3.01	5.86	9.43
RF1WM (mm)	576	576	576
RF1DM (mm)	323	323	323
RF1WY (mm)	584	584	584
RF1DY (mm)	226	226	226
RF2WM (mm)	619	619	619
RF2DM (mm)	637	637	637
RF2WY (mm)	460	460	460
RF2DY (mm)	113	113	113

Sri Lanka in the development stage. Total rice and wheat flour consumption in Sri Lanka over the last two decades has remained quite stable around 140 kg per capita. This is likely to increase slightly over the forecast period ending in 2005 with an increasing share taken up by wheat flour. An income elasticity of 0.1 for rice consumption, and 0.2 for wheat consumption were used.

Under these assumptions, total rice consumption in the baseline scenario will rise at 1.7 percent annually in the period 1995-2000 and 1.6 percent thereafter. Alternative demand growth scenarios are examined with 'low' and 'high' growth projections for population and per capita income.

Simulation Results

Baseline projections show that rice production will rise until year 2000 and decline thereafter (Table 5-10). The total rice paddy production in 1993 was projected to be 1.57 million tons. The total production is shown to increase 2.5 percent annually until year 2000 to reach 1.68 million tons of rice. The rice output is projected to decline one percent annually thereafter, reaching 1.58 million tons by year 2005.

According to the baseline scenario the gap between domestic rice supply and demand will increase over the period 1995-2005. The estimated annual rice requirement of

1.84 million tons in 1985 indicates a supply shortfall of 374 thousand tons (20 percent). Total rice requirement is predicted to reach 2.15 million tons by 2005 indicating a 584 thousand ton (27 percent) supply shortfall. According to these projections, the per capita annual rice consumption in 2005 increases to 104 kg from 100 kg currently. These consumption levels are well within the levels observed in Sri Lanka during the 1970s at the peak of the rice subsidy scheme. Under the baseline scenario, imports will have to rise by more than 50 percent over the 10 year period from 1995-2005.

The consumption of wheat is estimated to rise to 890 thousand tons by 2005, an increase of 21 percent over the present level of 720 thousand tons. Per capita wheat consumption will increase to 43 kg from 39 kg presently. These estimates assume that future policies do not drastically alter the relationship of prices between wheat and rice. In Sri Lanka, it has been observed that the substitution of wheat for rice in consumption is very high. With liberalization of rice trade and eventual elimination of the subsidy given to wheat flour, it is expected that the domestic retail prices of rice and wheat will move closer to each other, but not at a scale that would make a large shift in the relationship.

Changes in net import requirements under alternative income and population growth assumptions were also examined (Table 5-9). Higher income growth scenario leads

Table 5-10. Estimated Rice Requirement, Production, and Imports ('000 tons) under Alternative Scenarios 1995-2000

Year	Baseline Scenario[a]			Rice Imports					
				Income		Population[b]		Irrigation Investments	Research Investments
	Consumption	Production	Imports	Low (2%)	High (5%)	Low 1.0/0.9	High 1.5/1.4	3%[c]	5%[c]
1995	1841	1465	374	356	380	371	378	368	370
2000	1993	1677	327	316	351	283	337	250	318
2005	2147	1586	584	560	631	484	605	433	551

[a] For Baseline assumptions, population grows annually at 1.4 percent between 1996-2000 and 1.3 percent between 2001-2005; per capita income grows at 3 percent; irrigation investments decreases annually by 1 percent; and, agricultural research investments increases annually by 2 percent.
[b] Low population projection assumes 1 percent annual population growth between 1996-2000 and 0.9 percent between 2001-2005; and high population projection assumes 1.5 percent population growth between 1996-2000 and 1.4 percent between 2001-2005.
[c] Growth rates shown are annual increases in public investments on irrigation and rice research.

to a larger increase in the deficit from the baseline scenario than the higher population growth assumption. However, the changes in net imports from the baseline scenario for either income or population growth assumption were less than ten percent.

One option available to the government to counter the growing deficit in domestic rice supply is to increase investments in irrigation, research and extension. These scenarios were examined in the alternative simulations. However, the results of these simulations must be considered subject to some caveats. As discussed earlier, it is not realistic to assume increases in the overall level of irrigation as a solution to increasing rice supply as the unexploited irrigation capacity and land area are approaching their limits. It is suggested that in Sri Lanka, the only economically feasible and viable option left for irrigation is to go into a 'management stage' (Aluvihare and Kikuchi, 1991). This stage will be characterized by investments in maintaining and upgrading of irrigation structures as opposed to installing new capacity.

Two alternative scenarios were examined: a 3% annual increase in irrigation investments, and a 5% annual increase in rice research expenditures over the levels observed in 1993. An increase in irrigation investments is projected to have the largest influence on rice production by 2005. Imports required by year 2005 are estimated at 433 thousand tons; 25 percent less than the baseline imports. The increase in output consequent to a higher growth rate of research expenditure is modest compared to the impact of irrigation. However, growing deficit between domestic rice supply and the consumption needs can be overcome by modest increases in the current levels of technology-related investments.

Policy Implications

The simulation results point to a situation under which technology-related government-investment variables have a major role in future rice supplies. These results suggest several important implications for government rice policies in Sri Lanka.

The results establish the significant positive influence of the government investments in research and irrigation on rice output. Irrigation investments generated two effects in relation to land. It led to an expansion of the area that could be cultivated to rice (increase in the asweddumized area), and increased the intensity of land use by providing irrigation to existing rainfed land (increase in the share of the irrigated portion in asweddumized area). The impacts of research were mainly on the intensification of cultivation by replacing the existing low-yielding rice varieties with new high-yielding strains. It is known that HYVs perform best under favorable growing conditions similar to those provided under irrigation. Therefore, the existence of a well-harmonized growth pattern is indicated by the results.

Future expansion of the irrigation capacity in Sri Lanka is limited by the unavailability of new land suitable for irrigation and the high cost of development. This suggests that once the effects of the improvements already undertaken are fully played out, the output effects may start to subside. This makes expanding rice research investments even more critical, particularly if rice self-sufficiency is accepted as a policy goal. The stagnation in output that may occur due to halt in the growth of new irrigation capacity can be arrested by undertaking investments to increase efficiency of irrigation water distribution and use that would facilitate cultivation of a larger area under irrigation with the same stock of water. As all of the irrigation schemes in Sri Lanka are gravity systems with high conveyance losses undertaking investments to modernize these systems would both be realistic and profitable eventually.

Another policy implication relates to the effectiveness of direct price intervention by the government. Successive governments in Sri Lanka maintained a complex mix of price incentives of which the cornerstones were the guaranteed rice price scheme and the fertilizer subsidy scheme. The high priority assigned by successive governments in Sri Lanka to regulate output and input prices appears somewhat misguided given the weak price responsiveness shown by the producers. Operation of procurement price mechanisms ties up significant government resources. The evidence shows that the redirection of these scarce resources to improve the level and quality of irrigation and research facilities and services that increase productivity of rice to be a more efficient use. For example, before it was withdrawn the fertilizer subsidy scheme for rice cost the government nearly Rs. 700 million annually. Payments to cover the losses incurred in the operation of the guaranteed price scheme were also substantial. There is a lot of pressure from farmer groups and other interest sectors to re-activate these schemes. Instead, a more pragmatic approach for the government would be to maintain or even expand investments in rice research and irrigation.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

Research Summary

Government investments and policies play a major role in defining the long-term nature of food production programs in developing countries. Although the production of food is carried out mostly by private farmers, the provision of public good inputs and policy intervention by governments heavily influence the nature and scale of such activities.

Among the major food commodities, rice has been subjected to government control of an unparalleled scale because it is of critical importance to the welfare of millions of people in the developing world. Policies aimed at rice self-sufficiency were adopted by many Asian governments in the post-war era, primarily in response to the limitations encountered in meeting rice needs through the international market. The success in focusing on this singular objective and with the help of green revolution technologies many countries that depend on rice to meet a major part of their food supply have achieved this goal. However, now that rice supplies are adequate and prices are low, many Asian governments face a difficult decision: how to balance the need for reforming agriculture to generate surpluses and increase farm incomes while not risking the domestic rice supply levels? Research aimed at addressing such issues in a comprehensive manner need better information about the impact of government investments on producers' supply decisions.

This research attempts to answer questions relating to future strategy for rice production in Sri Lanka through an analysis of determinants of supply over the period 1974-1993. The main objective of the research was to ascertain the responsiveness of rice farmers to various price and non-price interventions with a view to determine how the future supply would behave under a more liberalized policy regime that may lessen the government role in agriculture and rely more on market forces.

Distinctive features of the world rice economy examined in chapter two demonstrated the reasons that forced the Asian rice economies to embrace policies that isolated themselves from the international rice market. It was observed that significant changes have taken place in the production, consumption and international trade in rice, particularly within the last two decades. As a result of the simultaneous adoption of self-sufficiency oriented policies by a majority of countries, as well as for other reasons, a surplus situation has occurred since the mid-1980s. Government policies in Sri Lanka in the post-independence period, i.e. since 1948, were found to conform to the general pattern for the rest of Asia.

This research developed and applied an analytical framework based on the endogenous technology approach to assess the supply responsiveness of Sri Lankan rice farmers to various incentives and investments influenced by government policies. This analytical framework provides a structure that can model separately the determination of the optimal combination of techniques or crops, and determination of optimal input and output combinations along a selected production function. Investments in technology and other quasi-fixed inputs are determined endogenously allowing examination of the dynamic effects of prices, investments and technology on output growth. Based on the concepts outlined in chapter three, an econometric model was specified and estimated. It consisted of three blocks each identifying equations that determine the levels of quasi-fixed inputs, rice area, and the yield. Seasonal and regional differences affecting these decisions were built into the model. An iteratively- seemingly unrelated regression (IT-SUR) procedure was used to estimate the blocks of equations in the system. The results were presented, and implications for policy discussed in chapter 5.

Conclusions of the Study

The study showed the importance of quasi-fixed inputs on the determination of rice supply response in Sri Lanka. It showed that the output response to incentives would be large if opportunities exist for expansion of irrigation, and provision of research outputs such as high-yielding varieties and improved technologies. Lack of suitable land for irrigation development excludes new irrigation expansion as a viable future growth option. This diminishes the prospects for expansion in rice output at levels that were possible in the past, even with significant increases in other investments.

Producers' were found to be relatively unresponsive to price changes leaving little opportunity for using reasonable price policies as an effective tool to induce large increases in output. Furthermore, the staple nature of the crop and poor economic conditions severely limits the price policy options that are available to the government. This suggests that the government cannot escape having to rely on trading in the world market to meet growing food needs.

With current trends towards dismantling of protectionism and other inhibitions to trade, as well as pressures from manufacturing and service sectors, the ability of Sri Lankan rice producers to press for policy changes are weakened considerably. This does not absolve the government from the pressures to find avenues to increase income earning potentials of large sectors of farm populations through non-distortionary measures. Public investments in research which is shown to be an under-invested area in many countries will continue to be an important means of serving these objectives.

The simulations showed that modest expansion of investments such as irrigation and research can increase the rice output to levels that would allow governments to keep import requirements well within physically manageable levels. Given the growth of the international rice market and the ability shown by it to efficiently deal with sharp short-term import demands, small producers such as Sri Lanka do not seem to expose themselves to a greater risk by resorting to strategies that increase dependance on the international market for meeting rice needs.

Limitations of the Study

The methodology employed in this study used a comprehensive framework for supply analysis. It endogenized the process of determination of levels of quasi-fixed inputs affecting the rice sector. The levels of quasi-fixed inputs influenced the composition of techniques implemented. Finally, the yields were determined by the techniques employed, levels of technology variables and inputs, and the environment. The model structure tracked the sequential nature of the decision process through time.

The model allowed separate treatment of spatial and temporal variations in the production structure, but did not permit tracing these back to changes in the levels of quasi-fixed inputs such as irrigation and research completely as data on the latter variables were not separated by geographical regions or cropping calendars. Better estimates of data under desired categorizations can only be obtained by referring to the primary reports that are often unaccessible. The need to record such information in a manner readily accessible to analysts need to be considered in reporting data.

The reporting of agricultural data is mostly confined to operations of government agencies, and little effort is made to collect data on complementary private sector activities. Private sector institutions play a major role in the provision of inputs such as seed and cultivation credit that are rarely covered in public statistics. A systematic procedure to collect and record private sector contributions needs to receive attention.

The importance of political economic considerations on the determination of government policies and strategies were recognized to have an important role, but could not be examined as there are hardly any indicators that can capture the influence of producer groups under most developing country situations. In most developing economies there is hardly any organized lobbying groups whose activities can be quantified. Creative means to devise variables that capture political economic influences in the developing country situations are needed.

BIBLIOGRAPHY

ANDERSON, KIM., and YUJIRO HAYAMI. *The Political Economy of Agricultural Protection.* Sydney, Australia: Allen and Unwin. 1986.

ALSTON, J., G. EDWARDS and J. FREEBAIRN. "Market Distortions and Benefits from Research." *American Journal of Agricultural Economics*, Vol. 70 (2): 281 - 288, 1988.

_________. and P. PARDEY. "Technical Change, Constraints and Incentives: The Damaging Consequences of Getting Policies Wrong." Paper presented at the Conference on Agricultural Technology: Current Policy Issues for the International Community and The World Bank, Airlie House, Virginia - USA. October, 1991.

_________, G. NORTON and P. PARDEY. *Science under Scarcity: Principles and Practice for Research Evaluation and Priority Setting*, New York: Cornell University Press, 1994.

ALUVIHARE, P. B., and M. KIKUCHI. *Irrigation Investment Trends in Sri Lanka: New Construction and Beyond*, Sri Lanka: International Irrigation Management Institute, 1991.

ANTLE, J. "Dynamics, Causality, and Agricultural Productivity." in S. Capalbo and J. Antle. Eds. *Agricultural Productivity: Measurement and Explanation*, Washington D.C.: Resources for the Future, 1988.

ASKARI, HOSSEIN and JOHN T. KUMMINGS. *Agricultural Supply Response: A Survey of the Econometric Evidence.* New York: Praeger, 1976.

_________., and JOHN T. KUMMINGS. "Estimating Agricultural Supply Response with the Nerlove Model: A Survey". *International Economic Review*, Vol. 18:257-292, 1977.

ATHUKORALA, PREMACHANDRA, and SISIRA JAYASURIYA. *Macroeconomic Policies, Crises, and Growth in Sri Lanka.* Washington D.C.: The World Bank, 1994.

BANSIL, P. C. *Ceylon Agriculture: A Perspective.* Delhi, India: Dhanapat Rai, 1971.

BAPNA, S.L.,

BARGHOUTI, SHAKWI, LISA GARBUS and DINA UMALI. *Trends in Agricultural Diversification - Regional Perspectives.* Washington D.C.: The World Bank, 1992.

BECKER, G. "A Theory of Competition among Pressure Groups for Political Influence." *Quarterly Journal of Economics*, Vol.93 (3): 372 - 400, 1983.

BHAGWATI, N. "Directly Unproductive Profit Seeking Activities." *Journal of Political Economy*, Vol.90 (4): 982 - 1002, 1982.

BINSWANGER, H. and V. RUTTAN. Eds. *Induced Innovation: Technology, Institutions and Development*, Baltimore: Johns Hopkins University Press, 1978.

BOGAHAWATTE, C. *Governmental Agricultural Policies and their Impact on Supply and Demand for Rice in Sri Lanka.* Ph.D. Dissertation, (Unpub.), Texas A & M University, 1982.

BOUIS, HOWARTH E. *Projections for Rice Supply and Demand Balances in Asia.* Final Report Submitted to Rockefeller Foundation. Washington D.C.: IFPRI., 1990.

__________. Rice in Asia: "Is it Becoming a Commercial Good?. Comment". *American Journal of Agricultural Economics*. Vol. 73(3): 522-527. 1991

CAPALBO, S. and J. ANTLE. Eds. *Agricultural Productivity: Measurement and Explanation*, Washington D.C.: Resources for the Future, 1988.

CAVALLO, D. and Y. MUNDLAK. Agriculture and Economic Growth in an Open Economy: The Case of Argentina, *International Food Policy Research Institute, Research Report No. 36*, Washington D.C., 1982.

CHAMBERS, R. *Applied Production Analysis. A Dual Approach*, United States: Cambridge University Press, 1988.

CLINE, PHILIP L. *Sources of Productivity in the United States Agriculture*. (Unpub) Ph.D. Dissertation, Oklahoma State University, 1975.

COEYMANS, J.E. and Y. MUNDLAK. "Sectoral Growth in Chile, 1962-82." *International Food Policy Research Institute, Research Report Manuscript*, Washington D.C., 1993.

COLMAN, DAVID. "A Review of the Arts of Supply Response Analysis". *Review of Marketing and Agricultural Economics*, Vol. 51:201-230, 1983.

DALY, REX F., R.G. HOFFMAN, F. NELSON, and H. WEINGARTEN. "Agriculture in the Vietnam Economy: A System for Economic Analysis." Washington D.C.: *US Department of Agriculture, Economic Research Service: FAE Report No. 164.* 1981.

DAVID, C., and KEIJIRO OTSUKA. *Modern Rice Technology and Income Distribution in Asia.* Boulder, Colorado: Lynne Reinner, 1990.

__________. "Differential Impact of Modern Rice Varieties Across Production Environments." *Food Policy*, Vol. (31): , 1992.

__________. and M. ROSEGRANT, *Asian Rice Economy: Issues and Agenda for Research.* (Mimeo.), IFPRI/IRRI, Washington D.C., 1991.

DAVIS, J., P. ORAM and J. RYAN. Assessment of Agricultural Research Priorities: An International Perspective. Australia: *ACIAR Monograph* No 4, 1987.

de GORTER, H. and D. ZILBERMAN. "On the Political Economy of Public Good Inputs in Agriculture." *American Journal of Agricultural Economics*, Vol. 72 (1): 131 - 147, 1990.

___________., and G. NORTON. "A Critical Appraisal of Analyzing the Gains from Research with Market Distortions." (Mimeo.) Department of Agricultural Economics. Cornell University, 1988.

____________, D. NIELSON and G. RAUSSER. "Productive and Predatory Public Policies: Research Expenditures and Producer Subsidies in Agriculture." *American Journal of Agricultural Economics*, Vol. 74 (1): 27 - 37, 1992.

EDIRISINGHE, NEVILLE. "Food Stamp Scheme in Sri Lanka: Distribution of Benefits and Impacts on Nutrition." *International Food Policy Research Institute, Research Report No. 15.* 1985.

EDWARDS, G. and J. FREEBAIRN. "The Gains from Research into Tradeable Commodities." *American Journal of Agricultural Economics*, Vol. 66 (1): 41 - 49, 1984.

EVENSON, ROBERT E. *The Contribution of Agricultural Research and Extension to Agricultural Production.* (Unpub) Ph.D. Dissertation, University of Chicago, 1968.

EVENSON, ROBERT E. 1983.

___________, and C. DAVID. *Adjustment and Technology: The Case of Rice.* Development Center Studies, OECD, 1993.

FAO. Rice: "Selected Aspects of Production, Trade and Price Policies." Rome, Italy: *FAO Economic and Social Development Paper. No 54*, 1985.

___. "Demand Prospects for Rice and Other Foodgrains in Selected Asian Countries." Rome, Italy: *FAO Economic and Social Development Paper. No. 97*, 1991.

___. *FAO Production Yearbook*, Rome - Italy: Various Years.

___. *FAO Fertilizer Yearbook*, Rome - Italy: Various Years.

FAWSON, CHRIS., C. RICHARD SHUMWAY, and ROBERT L. BASMANN. "Agricultural Production Technologies with Systematic and Stochastic Technical Change." *American Journal of Agricultural Economics*. Vol. 72(1): 182-189. 1990

FULGINITI, L. and R. PERRIN. "Prices and Productivity in Agriculture." *Working Paper Department of Economics. Iowa State University*. 1991.

GARDNER, B. "Efficient Redistribution through Commodity Markets." *American Journal of Agricultural Economics*, Vol. 65 (1): 225 - 234, 1983.

__________. *The Economics of Agricultural Policies*. New York: Macmillan Publishing Company, 1987a.

GAVAN, JAMES D. and INDRANI SRI CHANDRASEKERA. "The Impact of Public Foodgrain Distribution on Food Consumption and Welfare in Sri Lanka." *Wasington D.C.: International Food Policy Research Institute, Resesrch Report No. 13.* 1979.

GODFREY, L. *Misspecification Tests in Econometrics*, Great Britain: Cambridge University Press, 1988.

GOLLIN, RICHARD., and ROBERT E. EVENSON. "Genetic Resources and Rice Varietal Improvement." *Economic Growth Center Studies*, Yale University. 1993.

GRILICHES, ZVI. "Research Expenditures, Education and the Aggregate Agricultural Production Function" *American Economic Review*, Vol 54:961-974, 1964.

GRILICHES, ZVI. The Demand for Inputs in Agriculture and a Derived Supply Function. J. Farm Econ., 41:309-322, 1959.

GRILICHES, ZVI. Estimates of the Aggregate US Farm Supply Function. J. Farm Econ., 42:282-293, 1960.

GUNAWARDANA, P. J., and E. A. OCZKOWSKI. "Government Policies and Agricultural Supply Response: Paddy in Sri Lanka." *Australian Journal of Agricultural Economics*, Vol( ) :231-242., 1992.

HAYAMI, Y. and V. RUTTAN. *Agricultural Development: An International Perspective. Revised and Expanded Edition*, Baltimore: The Johns Hopkins University Press, 1985.

HENNEBERRY, SHIDA RASTEGARY. "The World Rice Market." *Giannini Foundation Information Series.* No.85-2. University of California, 1985.

__________. "A Review of Agricultural Supply Response for International Policy Models.", Washington D.C.: Agricultural Planning and Analysis Project, USAID/ABT Associates., 1986.

__________., and LUTHER G. TWEETEN A Review of International Agricultural Supply Response., *Journal of Food and Agribusiness Marketing*, Vol 2(3/4):49-95, 1991.

HERRMAN, JEANNETTE. "*Integration of the International Rice Market: Implications for Risk Management*"., *in,* "Managing Commodity Price Risks in Developing Countries." Stijn Claessens and Ronald C. Duncan (ed). The World bank. 1993.

HOSSAIN, M. 'Social science research at IRRI: General focus and priority issues'. Paper presented at the meeting of Social Scientists in the CGIAR Institutions. 1992.

HOUCK, JAMES P., and MARY E. RYAN. "Supply Analysis for Corn in the US: The Impact of Changing Government Programs". *American Journal of Agricultural Economics*, Vol. 54:184-191, 1972.

HUANG, JIKUN., CHRISTINA C. DAVID. "Structural Changes in Demand for Cereal Grains in Asia." Social Sciences Division, IRRI. 1991.

__________., and BART DUFF. "Rice in Asia: IS IT Becoming an Inferior Good Comment." *American Journal of Agricultural Economics*, Vol. 73:516-521. 1991.

HUFFMAN, W. and J. MIRANOWSKI. "An Economic Analysis of Expenditures on Agricultural Experiment Station Research." *American Journal of Agricultural Economics*, Vol. 63 (1): 104 - 118, 1981.

HUNTINGTON, S. and J. NELSON. *No Easy Choice. Political Participation in Developing Countries*, Cambridge: Harvard University Press, 1976.

INGCO., MERLINDA D. "Is Rice Becoming an Inferior Good? Food demand in the Philippines." Wahington D.C.: *Working Papers, International Economics Department., The World Bank.* 1991.

INTERNATIONAL RICE RESEARCH INSTITUTE. The World Rice Statistics. 1991.

__________. IRRI REPORTER. 1995

ITO, SHOICHI, WESLEY F. PETERSON. "Asian Rice Elasticities." *Rice Outlook and Situation Report*. USDA/ERS 1988.

ITO, SHOICHI, WESLEY F. PETERSON AND WARREN R. GRANT. Rice in Asia: Is it becoming and Inferior Good. *American Journal of Agricultural Economics*: Vol. 71:33-42. 1989.

KMENTA, JAN *Elements of Econometrics-Second Edition.* New York: McMillan, 1986.

KREI. (KOREA RURAL ECONOMICS INSTITUTE). "Studies for Improving Rice Marketing in Seoul area -Focusing on the Wholesale Market." Seoul, South Korea, 1984.

KRUEGER, A. *The Political Economy of Agricultural Pricing Policy- A Synthesis of the Political Economy in Developing Countries.* Baltimore: The John Hopkins University Press, 1991.

__________, M. SCHIFF and A. VALDES. "Agricultural Incentives in Developing Countries: Measuring the Effect of Sectoral and Economy wide Policies." *The World Bank Economic Review*, Vol. 2 (3): 255 - 271, 1988.

__________., M. SCHIFF and A. VALDES. *The Political Economy of Agricultural Pricing Policy. Volume III. Asia*, Baltimore: The John Hopkins University Press, 1991.

KUMAR, PADUMAN, and MARK W. ROSEGRANT. "Dynamic Supply Response of Rice and Other major Food Crops in India." *Second Workshop on Projections and Policy Implications of Rice Supply and Demand.* IRRI. 1993.

LAHIRI, KAJAL., and PETER SCHMIDT. "On the Estimation of Triangular Structural Systems." *Econometrica.* Vol. 46(5):1217-1221. 1978

LAU, LAWRENCE J., and PAN A. YOTOPOULOS. "Profit, Supply and Factor Demand functions." *American Journal of Agricultural Economics*, Vol. (64(1): 11-18. 1972.

LINDNER, R. and F. JARRETT. "Supply Shifts and the Size of Research Benefits." *American Journal of Agricultural Economics*, Vol. 60 (1): 48 - 58, 1978.

LOPEZ, RAMON E. :Application of Duality Theory to Agriculture." *Southern Journal of Agricultural Economics*. Vol. (4):353-365. 1982.

MANN, JITENDER S. "Food Demand pattern in Thailand." Washington D.C.: *US Department of Agriculture/ERS., Staff Report*. 1982.

McGUIRK, A. *Technological Change and Agricultural Growth in Punjab*. Ph.D. Dissertation, (Unpub.), Cornell University. 1988.

__________., and Y. MUNDLAK. Incentives and Constraints in the Transformation of Punjab Agriculture. *International Food Policy Research Institute. Research Report No 87*, Washington D.C., 1991.

__________., P. DRISCOLL, and J. ALWANG. "Misspecification Testing: A Comprehensive Approach." *American Journal of Agricultural Economics*, Vol. 75 (4): 1044 - 1055, 1993.

MUNDLAK, Y. Intersectoral Factor Mobility and Agricultural Growth. *International Food Policy Research Institute. Research Report No 6*, Washington D.C., 1978.

__________. *Agriculture and Economic Growth: Theory and Measurement*. Lecture Notes, Department of Economics. The University of Chicago, September 1986.

__________. "Endogenous Technology and the Measurement of Productivity", in S. Capalbo and J. Antle. Eds. *Agricultural Productivity: Measurement and Explanation*, Washington D.C.: Resources for the Future, 1988.

__________, D. CAVALLO and R. DOMENECH. Agriculture and Economic Growth in Argentina, 1913 - 84, *International Food Policy Research Institute. Research Report No 76*, Washington D.C., 1989.

NERLOVE, M. *The Dynamics of Supply: Estimation of Farmers' Response to price*. Johns Hopkins Press, Washington D.C. 1958.

NORTON, G. and J. DAVIS. "Evaluating Returns to Agricultural Research: A Review." *American Journal of Agricultural Economics*, Vol 16 (1): 121 - 128, 1981.

OEHMKE, J. "The Calculations of Returns to Research in Distorted Markets." *Agricultural Economics*. Vol 2 (4): 291 - 302, 1988.

_________. and X. YAO. "A Policy Preference Function for Government Intervention in the U.S. Wheat Market." *American Journal of Agricultural Economics*, Vol. 72 (3): 631 - 640, 1990.

PARDEY, P., S. KANG, and H. ELLIOTT. "The Structure of Public Support for National Agricultural Research Systems: A Political Economy Perspective." *Agricultural Economics*. Vol. 3 (4): 261 - 278, 1989.

PARDEY, P., S. ROBERT K. LINDNER, EDI ABDURACHMAN, STANLEY WOOD, SHENGGEN FAN, WILHELMINA M. EVELEENS, BIN SHANG, And JULIAN M. ALSTON. The Economic Returns to Indonesian Rice and Soybean research. AARD/ISNAR Paper. 1992.

__________ and B. CRAIG. "Causal Relationships between Public Sector Agricultural Research Expenditures and Output." *American Journal of Agricultural Economics*, Vol. 71 (1): 9 - 19, 1989.

__________, J. ROSEBOOM and J. ANDERSON. Eds. *Agricultural Research Policy: International Quantitative Perspectives*, Great Britain: Cambrige University Press, 1991.

PETZEL, TODD E., and MONKE ERIC A. "The Integration of the International Rice Market." *Food Research Institute Studies*. No. 17. No. 3:307-326. 1980.

PRAY, CARL E. "The Development of Asian Research Institutions: Under-investment, Allocation of Resources, and Productivity." *in* Evenson, R and C. Pray. *Research and Productivity in Asian Agriculture*. Cornell University Press, Ithaca, 1991.

ROSE, R. "Supply Shifts and Research Benefits: Comment." *American Journal of Agricultural Economics*, Vol. 62 (4): 834 - 837, 1985.

ROSE-ACKERMAN, S. and R. EVENSON. "The Political Economy of Agricultural Research and Extension: Grants, Votes and Reapportionment." *American Journal of Agricultural Economics*, Vol. 67 (1): 1 - 14, 1985.

ROSEGRANT, MARK W. "Irrigation Investment and Management in Asia. Trends, Priorities and Policy Distortions." *World Bank Conference on Agricultural technology*. Airlie House, Virginia, USA, 1991.

__________., and FAISAL KASRYNO. Food Crop Production Growth in Indonesia: Supply Response with Choice of Technique. (Mimeo). IFPRI, 1992.

RUTTAN, V. *Agricultural Research Policy*, Minneapolis: University of Minnesota Press, 1982.

SAS INSTITUTE INC. *SAS/ETS User's Guide, Version 6.04*, Cary, North Carolina, 1992.

SCHIFF M. and A. VALDES. *The Political Economy of Agricultural Pricing Policy. Volume 4. A Synthesis of the Economics of Developing Countries*, Baltimore: The John Hopkins University Press, Washington D.C., 1992.

SCHNEPF, RANDALL D. International Rice Situation and Outlook. (Mimeo) US Department of Agriculture-ERS, Washington D.C., 1994.

__________., and BRYAN JUST. "Rice: Background for 1995 Farm Legislation." *US Department of Agriculture-ERS. Staff Studies, No. 713*, Washington D.C., 1995.

SIAMWALLA, A and S. HAYKINS. The World Rice Market: Structure, Conduct and Performance. *International Food Policy Research Institute,Research Report* No. 39, Washington D.C., 1983.

SIDDIQUI, REHENA., and ATHER M. AHMED. "Supply Response in Agriculture: A Provincial Level Analysis." *Second Workshop on Projections and Policy Implications of Rice Supply and Demand.* IRRI. 1993.

SLAYTON, THOMAS M. "Some pieces of the world rice puzzle." *Rice Situation and Outlook Report.* Washington D.C.: USDA-ERS, 1984.

SPANOS, ARIS. *Statistical Foundations of Econometric Modelling.* Great Britain, Cambridge University Press. 1986.

SRI LANKA, GOVERNMENT OF., Central Bank. *Annual Report.* 1991.

__________. Central Bank. *Annual Report.* 1993.

__________. Department of Census and Statistics. *"Statistical Abstracts."* Various issues. 1975- 1990.

__________. Department of Census and Statistics. "Labor Force Participation Survey." 1994.

__________. National Fertilizer Secretariat, *Annual Review of Fertilizer*, Various Years. 1991.

__________., Paddy Marketing Board. *Statistical Bulletin*. 1990.

SWAMI,

TIMMER, C. PETER. *Agriculture and The State: Growth, Employment, and Poverty in Developing Countries*. Ithaca: Cornell University Press. 1991.

TYERS, RODNEY, and KIM ANDERSON. *Distortions in World Food Markets*. Cambridge: Cambridge University Press. 1992.

USDA/ERS. Rice: *Situation and Outlook Report*. 1992.

USDA/ERS. *Global Food Assessment: Situation and Outlook Report*. (1992).

WONNACOTT, R. and T. WONNACOTT. *Econometrics*, Canada: John Wiley & Sons, Inc., 1979.

WORLD BANK, THE. *Price Projections for Major Primary Commodities*. Washington D.C: Vol.1. 1993.

__________. "*World Development Report*." 1986.

YETLEY, MERVYN J., and SOVAN TUN. "Household Demand Analysis for Assessing Nutritional Impact of Development Programs." *US Department of Agriculture- ERS, Staff Report*, No. AGES 810806. 1981.

ZELLNER, ARNOLD. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *American Statistical Association Journal*. 348-367. 1962.

APPENDIX A

Data used in the Analysis

Table A.1 Total (Asweddumized) Rice Area

	Wet Zone [a]		Dry Zone [b]	
Year (1)	Irrigated (2)	Rainfed (3)	Irrigated (4)	Rainfed (5)
		(ha)		
1974	49214	98800	316034	142629
1975	48748	102794	327825	142431
1976	48290	103905	333420	143719
1977	48073	104896	341438	148728
1978	47521	105041	363122	150486
1979	44465	105534	355348	148099
1980	43549	105760	357162	147429
1981	47083	103681	368174	149288
1982	47566	102864	384091	152518
1983	48140	103042	393073	154798
1984	47881	103151	397530	154719
1985	45533	100020	402401	154180
1986	49963	98926	413880	153913
1987	51387	97364	423162	154095
1988	52081	96234	427421	151987
1989	52056	95794	431251	151818
1990	51541	92636	435126	151024
1991	51489	92081	438377	150951
1992	51080	91810	444420	149680
1993	49460	87270	446240	145230

(a) Wet zone includes the districts of Colombo, Galle, Gampaha, Kalutara, Kandy, Kegalle, Nuwaraeliya and Ratnapura.

(b) Dry zone includes the remaining districts including the intermediate zone, Mahaweli-H and Uda Walawe projects.

Notes: (1) - In the case of Maha season which extends over two calendar years, the year shown refers to the latter year.
(2) - (5) - Asweddumized area is reported for the beginning of maha season.

Sources: Sri Lanka, Department of Census and Statistics, *Statistical Abstracts*, various issues.

Table A.2a **Area Planted to Rice and Cash Crops**
Maha Season:

	Wet Zone [a]		Dry Zone [a]		
Year (1)	**Irrigated (2)**	**Rainfed (3)**	**Irrigated (4)**	**Rainfed (5)**	**Cashcrop (6)**
			(ha)		
1974	46653	91165	254929	119297	60920
1975	46704	97279	188343	105840	75410
1976	46319	97974	207384	105905	74840
1977	45759	97522	272559	118646	73950
1978	45014	97711	306152	122293	69060
1979	40149	94180	313629	128334	54770
1980	42598	93516	312532	125034	61730
1981	44738	92347	327981	131879	68350
1982	45228	92343	305064	124853	69630
1983	45954	93206	315655	128072	74480
1984	45295	92027	341259	127860	76030
1985	46270	88911	324395	109167	75960
1986	46553	88238	324341	96077	75680
1987	46929	85484	289204	86213	80300
1988	46694	82720	323729	91485	82350
1989	46999	82721	263772	75358	66820
1990	47485	82676	304613	92652	85440
1991	46838	80838	291485	81348	81490
1992	46566	81593	324844	95187	79170
1993	45695	78611	331849	89534	83710

(a) See notes for Table A.1 for definitions of the wet and dry zones.

Notes: (1) - In the case of Maha season which extends over two calendar years, the year shown refers to the latter year.
(2) and (4) - Irrigated area is computed as the sum of area under major irrigation and minor irrigation.
(8) - Cash crop group includes area planted to cowpea, chilli, greengram, maize and soybean.

Sources: Sri Lanka, Department of Census and Statistics, *Statistical Abstrcts*, various issues.

Table A.2b Area Planted to Rice and Cash Crops
Yala Season:

	Wet Zone		Dry Zone		
Year (1)	Irrigated (2)	Rainfed (3)	Irrigated (4)	Rainfed (5)	Cashcrop (6)
			(ha)		
1974	42321	88233	133315	27726	30000
1975	42215	91925	92873	24656	30060
1976	35120	85309	113439	25902	31140
1977	38605	91181	129579	28247	24250
1978	36636	87266	148240	28413	23740
1979	30237	73483	137098	19853	22040
1980	31912	76728	138104	24584	26410
1981	34460	83052	141149	21513	33200
1982	36110	82626	132999	25147	37790
1983	27442	44059	149328	20488	33440
1984	35221	82515	236584	29448	30790
1985	37148	78102	175261	21437	35510
1986	37691	78366	198551	25502	37980
1987	35361	63581	152613	21841	27330
1988	39263	74672	182574	26673	29130
1989	35475	62605	146971	13057	31540
1990	39119	73775	125938	20827	34620
1991	37304	71701	186271	20864	30410
1992	32719	51634	147608	23023	22740
1993	33279	59757	174237	21331	26200

Notes: See notes for the Table A.2a.

Table A.3a Average Yields of Rice and Cash Crops
Maha Season:

	Wet Zone [a]		Dry Zone [a]		
Year (1)	Irrigated (2)	Rainfed (3)	Irrigated (4)	Rainfed (5)	Cashcrop (6)
		(Tons/ha)			
1974	2.9797	2.0109	2.7721	1.9252	1.08
1975	2.8705	1.8885	2.7359	2.0187	0.98
1976	2.4664	1.9869	2.8246	2.0369	1.05
1977	2.6356	1.8869	3.1102	2.2839	1.10
1978	2.7209	1.8913	3.1971	2.1425	1.08
1979	2.8085	2.1803	3.1998	2.3423	1.19
1980	2.8956	2.2223	3.3362	2.4309	1.28
1981	2.8400	2.4788	3.3340	2.6382	1.25
1982	3.1624	2.7564	3.6283	2.5083	1.26
1983	3.4680	2.7794	4.1410	2.9775	1.55
1984	3.2288	2.8491	3.2525	2.3093	2.13
1985	3.3543	2.7936	3.8642	2.9608	2.90
1986	3.4023	2.7238	3.9910	2.8987	2.96
1987	3.3774	2.9605	4.1353	2.7215	2.91
1988	3.2720	2.8519	3.7665	2.8535	3.07
1989	3.4460	2.8400	3.7847	2.7864	2.92
1990	3.3682	2.9484	3.9686	2.7380	3.20
1991	3.2425	2.7799	4.0673	3.0057	3.16
1992	3.3480	2.9389	3.8088	2.9986	2.67
1993	3.1789	2.7979	3.9172	2.8812	3.01

(a) See notes for Table A.1 for the definitions of wet and dry zones.

Notes: (1) - (4) - Average rice yields are computed from the production and harvested area figures for the districts.
(5) - Average yield of cash crops is computed as an index with the prices as weights.

Sources: Sri Lanka, Department of Census and Statistics, *Statistical Abstrcts*, various issues.
Sri Lanka, Department of Agriculture, *Administrative Report of the Director* and other publications for data for the period 1968-1974.

Table A.3b **Average Yields of Rice and Cash Crops**
Yala Season:

	Wet Zone		Dry Zone		
Year (1)	**Irrigated (2)**	**Rainfed (3)**	**Irrigated (4)**	**Rainfed (5)**	**Cashcrop (6)**
		(Tons/ha)			
1974	2.5154	1.7425	2.3355	1.9585	0.95
1975	2.2720	2.1893	2.4365	1.9957	0.93
1976	2.2414	1.4413	2.6099	1.5480	0.92
1977	2.4803	1.7191	2.5876	2.0576	1.04
1978	2.5339	1.7243	2.7994	1.9611	1.09
1979	2.5235	1.8565	3.0491	2.0300	1.01
1980	2.7219	2.1865	3.3561	3.1767	1.26
1981	2.7883	2.2038	3.4063	3.1119	1.00
1982	3.1356	2.3560	3.9606	3.3187	1.07
1983	3.1456	2.2319	4.0566	3.5669	1.45
1984	3.0177	2.3639	3.4492	2.9095	2.99
1985	3.0655	2.3861	3.8150	3.2935	3.46
1986	3.0415	2.4457	3.7101	2.6099	3.06
1987	3.0532	2.3700	3.9013	3.1652	3.27
1988	3.1176	2.5235	3.8118	2.9911	3.20
1989	3.2679	2.3781	3.6836	2.7246	2.90
1990	3.1341	2.5821	3.3349	2.2624	3.30
1991	2.7442	2.1376	3.4758	2.6494	3.66
1992	2.9805	2.5006	3.5743	3.2857	2.53
1993	2.9078	2.2995	4.0538	2.5860	2.53

Notes: See notes for the Table A.3a.

Table A.4 Prices of Rough Rice and Fertilizer

	Maha Season			Yala Season		
YEAR (1)	Rice-Wet Z. (2)	Rice-Dry Z. (3)	Fertilizer (4)	Rice-Wet Z. (5)	Rice-Dry Z. (6)	Fertilizer (7)
			(Rs/ton)			
1974	2326.67	1856.67	530	2163.33	1826.67	529
1975	2270.00	2110.00	2665	2006.67	2086.67	1866
1976	1873.33	1820.00	1866	1893.33	1853.33	1333
1977	1783.33	1763.33	1052	1680.00	1610.00	1000
1978	2026.67	1940.00	1012	1976.67	1963.33	1787
1979	1993.33	1916.67	1707	2026.67	1976.67	1638
1980	2220.00	2086.67	980	2346.67	2446.67	980
1981	3056.67	3046.67	980	2993.33	3183.33	2140
1982	3436.67	3356.67	2785	3316.67	3320.00	2785
1983	3363.33	3236.67	2850	3496.67	3570.00	2785
1984	3583.33	3566.67	2850	3430.00	3353.33	2850
1985	3830.00	3903.33	2850	3660.00	3590.00	2850
1986	3856.67	4006.67	2850	3753.33	3890.00	2850
1987	3923.33	4120.00	2850	3973.33	3956.67	2850
1988	4090.00	3920.00	2850	4143.33	3866.67	2850
1989	4976.67	4786.67	3650	4910.00	5463.33	3650
1990	7573.33	7886.67	3650	7126.67	6853.33	8000
1991	7413.33	7373.33	7800	7036.67	6730.00	9600
1992	7863.33	7670.00	10300	8180.00	7773.33	9850
1993	8200.00	7953.33	9850	8306.67	8070.00	9850

Notes: (1) and (2) - Rice prices are computed as average of the monthly farm gate prices for selected districts for the months of January, February and March. Wet zone districts include Colombo, Galle, Gampaha, Kalutara, Kandy, Kegalle, Matara and Ratnapura. Dry zone districts include Ampara, Anuradapura, Baticoloa, Hambantota, Jaffna, Kurunegala, Moneragala, Mullaitivu, Polonnaruwa, Trincomalee, and Vavuniya.

Sources: (2), (3), (5) and (6) - Sri Lanka, Department of Census and Statistics, *Statistical Abstrcts*, various issues, for the period 1977-1993, and, Sri Lanka, Department of Census and Statistics, *Producer Prices of Agricultural Products,* (unpublished), for years 1968-1976.

(4) and (7) - Sri Lanka, National Fertilizer Secretariat, *Annual Review of Fertilizer*, various years between 1980-1993, and, Sri Lanka, Department of Agrarian Services, *Administrative Report*, various years between 1967-1980.

Table A.5a **Net Revenue of Rice and Cash Crops[1]**
Maha Season

	Wet Zone [a]		**Dry Zone [a]**		
Year (1)	**Irrigated** (2)	**Rainfed** (3)	**Irrigated** (4)	**Rainfed** (5)	**Cashcrop** (6)
			(Rs/ha)		
1974	15462.83	9898.88	9986.52	6909.28	1046.00
1975	12887.42	7857.27	9755.48	6479.56	863.89
1976	9166.26	5285.55	7223.11	4528.37	821.18
1977	6890.00	4005.98	5771.46	3462.10	916.76
1978	6471.80	3696.64	5469.75	2961.60	730.33
1979	4677.39	2285.86	5706.03	3402.91	380.64
1980	4952.36	2645.92	3543.60	1206.81	450.48
1981	5973.19	3675.59	7437.06	4515.26	292.16
1982	5452.27	3187.36	5504.86	2781.83	323.46
1983	4625.99	3105.96	4377.01	2213.57	264.35
1984	3786.92	2656.57	3933.01	1936.46	280.29
1985	4868.26	3778.80	5507.42	3177.14	255.89
1986	4716.17	3561.55	5504.63	3284.76	419.76
1987	4096.75	2791.40	3749.28	1467.27	445.90
1988	3941.23	2671.91	4384.26	2034.13	237.97
1989	4468.27	3250.06	4412.08	2096.33	426.95
1990	8334.65	6553.09	9292.76	6020.52	374.40
1991	6224.36	4837.76	7543.75	4581.16	625.74
1992	5172.09	4063.15	6497.58	3751.83	693.26
1993	3858.92	2857.34	5011.44	2976.66	800.89

[1] Deflated by implicit GDP Deflator 1986=100

(a) See notes for Table A.1 for definitions of the wet and dry zones.

Notes: Computed as averages for the selected districts.

Net Revenues are estimated as gross revenue less cost of fertilizer and cash inputs. Costs are computed from the district fertilizer usage statistics obtained from the National Fertilizer Secretariat and the cost of cultivation studies of the Department of Agriculture.

Table A.5b **Net Revenue of Rice and Cash Crops**[1]
Yala Season

	Wet Zone		Dry Zone		
Year (1)	**Irrigated (2)**	**Rainfed (3)**	**Irrigated (4)**	**Rainfed (5)**	**Cashcrop (6)**
			(Rs/ha)		
1974	13083.18	8156.85	9949.92	7814.51	1586.36
1975	10162.34	5920.16	9914.79	8153.73	1295.14
1976	8424.53	5104.95	7244.32	5536.14	1285.87
1977	5384.43	3302.19	4519.21	3166.91	1363.96
1978	5005.15	2609.87	4980.96	3291.63	1155.73
1979	4847.23	2542.93	5040.84	3338.54	593.90
1980	4524.04	2435.50	4433.21	2417.85	663.57
1981	4905.04	2329.19	4936.22	2331.15	649.67
1982	4786.91	2371.30	5291.86	3321.05	350.55
1983	4685.58	2697.56	5742.29	4389.05	365.87
1984	4209.95	2440.58	5169.68	4325.28	550.51
1985	4325.26	2228.64	5212.16	4331.50	920.22
1986	3934.80	1774.00	5270.58	4141.12	1547.63
1987	3366.54	1353.22	3771.84	2310.76	1336.07
1988	3157.51	1353.77	3329.57	1939.51	630.27
1989	3490.39	1577.56	5699.21	3687.44	1208.48
1990	6124.04	3777.37	7179.71	4865.04	1030.93
1991	5058.37	2916.24	4944.89	2582.75	1660.94
1992	4116.59	1718.77	4032.94	1871.96	2610.10
1993	3189.54	1148.47	3151.00	1336.17	1414.60

[1] Deflated by implicit GDP Deflator 1986=100

Notes: See notes for the Table a.5a.

Table A.6 Total Expenditure for Irrigation, Rice Research, and Extension, 1948-1993

Year	Irrigation	Research	Extension
(1)	(2)	(3) (Rs. Million)	(4)
1948	18.1	-	-
1949	42.8	-	-
1950	62.1	-	-
1951	75.1	0.8	2.0
1952	103.7	1.1	1.7
1953	78.5	0.6	1.6
1954	50.0	3.2	1.7
1955	62.5	3.1	2.0
1956	53.8	1.2	1.8
1957	55.8	1.1	1.7
1958	45.0	6.1	5.3
1959	59.0	7.1	6.5
1960	42.8	8.1	7.6
1961	52.2	8.4	7.1
1962	46.2	8.1	5.9
1963	30.1	7.4	5.7
1964	37.9	6.9	5.8
1965	52.4	1.6	2.2
1966	43.8	1.6	2.2
1967	77.6	1.6	2.2
1968	87.4	4.1	5.6
1969	96.8	5.8	13.3
1970	97.3	6.7	14.2
1971	82.2	6.6	16.0
1972	88.7	6.9	20.1
1973	146.7	5.7	17.7
1974	119.5	5.7	22.2
1975	173.2	7.1	19.5
1976	194.0	6.9	29.6
1977	183.1	13.4	42.2

(Contd.)

1978	421.2	17.4	54.9
1979	787.8	20.3	61.5
1980	1117.9	22.4	80.7
1981	2660.2	31.0	110.8
1982	3341.7	29.0	78.6
1983	3371.7	42.1	110.2
1984	3251.7	38.4	113.6
1985	3317.5	55.7	125.6
1986	2794.3	54.2	143.8
1987	3123.6	32.4	119.3
1988	2458.2	55.0	173.4
1989	1922.1	53.7	185.3
1990	1731.7	48.1	156.4
1991	2081.8	48.2	161.6
1992	1989.5	55.7	170.3
1993	1932.0	61.6	177.4

Sources:(1) - Year refers to calendar year.
(2) - Upto 1988, Aluvihare and Kikuchi, 1991, Irrigation Investments Trends in Sri Lanka, Table AI.6, and, 1989-1993, computed from the *Budget Estimates,* for the Department of Irrigation, Department of Agrarian Services, and Mahaweli Economic Agency.
(3) and (4) - Sri Lanka, Department of Agriculture, *Budget Estimates,* various years, 1950-1995.

Table A.7 Stocks of Irrigation, Research, and Extension

Year (1)	Irrigation (2) (Rs. Mill)	Research (3) (log)	Extension-Wet (4) (log)	Extension -Dry (5) (log)
1974	16450	16.7943	12.1878	11.3567
1975	16775	16.8003	12.1149	11.2671
1976	17118	16.8020	12.0622	11.1908
1977	17339	16.8040	12.0522	11.1624
1978	18104	16.7971	12.1856	11.2743
1979	19353	16.7790	12.3434	11.4112
1980	20400	16.7675	12.4978	11.5421
1981	22813	16.7658	12.5891	11.6185
1982	25402	16.7741	12.6185	11.6338
1983	27328	16.7971	12.6059	11.6050
1984	28761	16.8327	12.5265	11.5038
1985	30112	16.8831	12.4953	11.4530
1986	30984	16.9445	12.4791	11.4194
1987	31961	16.9917	12.4974	11.4210
1988	32299	17.0278	12.5076	11.4136
1989	32177	17.0504	12.5072	11.3979
1990	31820	17.0656	12.5083	11.3872
1991	31536	17.0768	12.4500	11.3170
1991	31536	17.0768	12.4500	11.3170
1992	31177	17.0858	12.3417	11.1946
1993	30765	17.0928	12.2383	11.0703

Note: See notes for the Table A6 and the text for computation.

Table A.8 Estimates of Profitability of Newly Developed Rice Land

	Wet Zone [a]		Dry Zone [a]	
Year	Irrigated	Rainfed	Irrigated	Rainfed
(1)	(2)	(3)	(4)	(5)
		(Rs. Mill.)		
1974	33272.20	22799.49	25765.17	20449.91
1975	29038.25	19801.91	26881.35	21524.67
1976	23359.41	16151.54	21420.65	16702.90
1977	17607.53	12659.43	16887.83	13033.46
1978	18421.14	13329.94	18691.14	14225.36
1979	16179.36	11436.75	16579.68	12290.94
1980	15475.09	11088.42	16953.53	12324.71
1981	17315.77	12519.62	20047.74	14302.59
1982	18338.09	13694.80	20703.36	15586.56
1983	16564.49	13110.18	19042.70	15094.82
1984	15335.92	12309.64	17199.63	14062.61
1985	16808.25	13649.61	18998.44	15464.92
1986	16769.25	13511.44	19459.03	15734.52
1987	16569.47	13301.60	18838.65	14670.87
1988	15503.25	12485.52	17437.96	13367.77
1989	16844.91	13799.22	20827.27	15912.33
1990	21303.22	17261.65	24338.07	18449.78
1991	19261.42	15830.37	21621.34	15736.95
1992	18967.12	15618.94	21370.31	15699.32
1993	17714.31	14778.05	19460.05	14841.17

(a) See notes for Table A.1 for definitions of the wet and dry zones.

Table A.9a Pre-Plant and Post-Plant Rainfall Received - Maha Season

	Wet Zone [a]		Dry Zone [a]	
Year (1)	Pre-Plant (2)	Post-Plant (3)	Pre-Plant (4)	Post-Plant (5)
		(mm)		
1974	739	428	514	548
1975	678	399	352	379
1976	1256	276	544	484
1977	956	417	576	388
1978	1053	364	758	353
1979	1019	345	714	419
1980	1242	288	839	240
1981	897	400	606	319
1982	941	189	606	188
1983	1086	259	664	288
1984	768	809	465	1179
1985	781	407	562	376
1986	924	619	585	653
1987	768	286	488	314
1988	1137	301	631	282
1989	802	196	483	310
1990	783	315	638	358
1991	770	437	640	566
1992	830	164	621	374
1993	974	163	747	286

(a) See notes for Table A.1 for definitions of the wet and dry zones.

Notes: Wet Zone rainfall is computed from the average monthly rainfall for 12 locations, and the Dry zone from the average monthly rainfall for 19 locations. Planting period for maha season constitute the months of October and November and growing period the months of December and January.

Sources: Sri Lanka, Department of Meteorology, Daily Rainfall Records for Meteorological Stations, (Unpub.).

Table A.9b Pre-Plant and Post-Plant Rainfall Received - Yala Season

	Wet Zone		Dry Zone	
Year (1)	Pre-Plant (2)	Post-Plant (3)	Pre-Plant (4)	Post-Plant (5)
		(mm)		
1974	803	1044	306	186
1975	764	882	425	304
1976	561	530	223	41
1977	794	926	400	243
1978	695	871	346	232
1979	448	739	207	178
1980	463	535	279	119
1981	515	665	226	191
1982	703	1067	371	252
1983	277	630	147	172
1984	852	965	460	171
1985	504	949	303	225
1986	488	374	303	89
1987	418	424	266	105
1988	568	771	378	165
1989	442	931	297	391
1990	596	722	389	328
1991	498	821	394	364
1992	385	975	277	322
1993	556	980	292	282

Notes: See Notes for the Table A.13a.

Notes: Planting period for maha season constitute the months of march and April and the growing period the months of may and June.

APPENDIX B

MISSPECIFICATION TESTS

The probabilistic structure underlying the linear regression model,

$y_t = \beta \mathbf{X}_t + \epsilon_t$, t=1, 2, ..,T,

can be summarized in several key assumptions. The following set of assumptions is commonly used in discussing misspecification tests: (1). Normality, (2). Functional form, (3). Homoskedasticity, (4). Parameter stability, (5). Independence, (6). Weak exogeneity, and (7). No perfect collinearity (McGuirk et al., 1993). Of these assumptions (1) - (5) are directly testable, (6) is not directly testable, and (7) is uninteresting as if is not held, estimation by OLS is impossible. The assumptions pertaining to normality, homoskedasticity, and independence were tested for all the equations in individual block.

I. Normality:

D'Agostino-Pearson K^2 third and fourth sample moment tests is used to test normality (D'Agostino, 1990). This is done using a skewness-kurtosis test. The test statistic is,

$$B.1 \qquad \tau_N = \left(\frac{T}{6} (\alpha_3)^2 + \frac{T}{24} (\alpha_4 - 3)^2 \right), \qquad H_0 \underset{a}{\sim} \chi^2_{(2)}$$

Where, T is the number of observations, α_3 is the sample skewness coefficient or third central moment, and α_4 is the sample kurtosis coefficient or fourth central moment.

II. Homoskedasticity:

A reset type test is conducted where an F-statistic is used to assess the significance under the hypotheses, H_0: $\Delta^{'} = 0$, against H_1: $\Delta^{'} \neq 0$

$$(B2) \qquad u_t^2 = \alpha + \Delta^{'}\Psi_t + \nu_t,$$

where, u_t^2 = squared residuals, $\Psi_t \equiv (y_t, y_t^2)$, or predicted values of y, and squared predicted values respectively.

III. Independence:

A special case of the Lagrange multiplier test proposed by Breusch and Godfrey (1978), which can be used in the presence of lagged independent variables, is used to test for independence. Independence is examined by assessing the significance of $\gamma^{'}$ in the auxiliary regression,

$$(B3) \qquad u_t = \beta_0^{'} X_t + \gamma^{'} u_{t-1} + \nu_t,$$

using a t-type test, where u_t, and u_{t-1} are current and one period lagged residuals from the equation being tested.

The p-values of tests conducted for individual equations are reported in the table B.1.

Table B.1 Results of Misspecification Tests for Normality, Homoskedasticity and Independence

Equation	Normality	p-Values Homoskedasticity	Independence
Quasi-Fixed Input Block			
LTAIW	0.9479	0.8113	0.0972
LTARW	0.8574	0.2354	0.2966
LTAID	0.6977	0.0118	0.2455
LTARD	0.5312	0.0008	0.0598
Area Block			
LAIWM	0.9385	0.0001	0.9972
LARWM	0.4039	0.6304	0.0488
LAIDM	0.4106	0.1280	0.8221
LARDM	0.4198	0.3068	0.4655
LACDM	0.0007	0.8020	0.9179
LAIWY	0.0663	0.4434	0.9302
LARWY	0.8445	0.3997	0.9346
LAIDY	0.6392	0.4855	0.2965
LARDY	0.7671	0.0195	0.9622
LACDY	0.3764	0.7963	0.8758
Yield Block			
LYIWM	0.7562	0.5285	0.2835
LYRWM	0.7876	0.1040	0.9993
LYIDM	0.4938	0.8341	0.9999
LYRDM	0.3478	0.0392	0.9991
LYCDM	0.2678	0.3379	0.7996
LYIWY	0.0494	0.6447	0.9967
LYRWY	0.5089	0.9322	0.9658
LYIDY	0.9436	0.5417	0.8443
LYRDY	0.7425	0.1328	0.9999
LYCDY	0.6794	0.0146	0.3214

VITA

Nihal Kirthi Atapattu was born on February 12, 1953 in Colombo, Sri Lanka. He completed his primary and secondary education at Kahanda Maha Vidyalaya and Vidyaloka Vidyalaya, Galle. He entered the University of Peradeniya in 1974 from Mahinda College, Galle. Following conferral of Bachelor of Science degree in Agriculture in 1978, he joined the Rubber Research Institute of Sri Lanka as an Agricultural Economist. In 1980 he joined the Sri Lanka Department of Agriculture as an Agricultural Economist and worked at the head office in Peradeniya and Angunakolapelessa Regional Research Station. He completed his M.S. degree in Agricultural Economics at the Virginia Tech between 1984-1986 and returned to Sri Lanka. He worked in the Head Office of the Department of Agriculture from 1986 - 1991 until commencing his Ph.D. program in Agricultural and Applied Economics at the Virginia Tech University in 1992. He received Ph.D. degree in June, 1996.

Nihal Kirthi Atapattu