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THE PAKISTAN AGRICULTURAL DEVELOPMENT MODEL: AN ECONOMIC EVALUATION OF AGRICULTURAL RESEARCH AND EXTENSION EXPENDITURES

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ABSTRACT

Pakistan must not only sustain its present agricultural output growth rate, but must increase it if the country is to avoid large food import bills and balance of payments problems. Pakistan's increasing population, the desire for improved nutritional standards fostered by moderately rising incomes and the increasing dependence on raw and processed agricultural products as a source of foreign exchange puts a heavy demand on Pakistan's agricultural sector. The future growth in agricultural output and productivity that Pakistan desires is a function of the agricultural development model it pursues and the committment to which it is pursued.

The purpose of this study was to investigate Pakistan's agricultural development model, describe it and its environment and appraise its effectiveness. First, a descriptive appraisal was conducted taking the form of relating Pakistan's agricultural development model to that of a "science-based" agricultural development model. This model, used by developed countries and most underdeveloped countries, relies on the natural sciences, management sciences and social sciences to produce and disseminate new technologies and guide institutional development. Secondly, empirical studies employing 1) an index number approach and 2) a total factor productivity model, were used in estimating the benefits and rates of return to expenditures in agricultural research and extension.

The descriptive appraisal indicated that while Pakistan pursues a science-based model, it has not met with complete success. Low funding levels, inadequate numbers of trained professionals and inadequate equipment and facilities have constrained research and extension efforts. Also, input and product market institutions have developed such that they militate against a more intensive use of inputs. Despite existing problems in the Pakistan agricultural system, the empirical results indicate that expenditures on agricultural research and extension pay a favorable rate of return. The marginal rates of return to investments in wheat research and extension were between 60 to 85 percent and to maize research and extension, 18 to 26 percent. The overall marginal rate of return to all expenditures on agricultural research and extension in Pakistan was between 55 to 65 percent.

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Chapter 1

INTRODUCTION

1.1 Introduction

Agriculture is Pakistan's largest single sector of the economy and accounted for 30.1 percent of the Gross Domestic Product (GDP) in 1981-82 (Table 1.1). The sector employs 13.3 million workers which accounts for 56 percent of Pakistan's total labor force (Pakistan Economic Survey, 1981-82). The agricultural sector is also an important source of foreign exchange earnings. Exports of rice accounted for 19.1 percent of the total value of export earnings in 1980-81 (Table 1.2). Cotton exports have also become a large contributor to export earnings and accounted for 17.8 percent of the value of total export earnings in 1980-81. In total, raw agricultural products accounted for 48.3 percent of the value of all Pakistan's exports (Table 1.1).

Raw agricultural products such as cotton, wool and leather provide the materials for many of Pakistan's industries. The value added and employment opportunities provided by these industries make major contributions to Pakistan's GNP. Goods such as cotton yarn, cotton cloth, carpets and leather which are manufactured from raw agricultural products accounted for 26 percent of the value of total export earnings. When taken as a total, raw agricultural products and manufactured agricultural products provided Pakistan with over 75 percent of the value of its foreign exchange earnings.

The performance of the agricultural sector also influences the trade balance with respect to the value of agricultural products that

Table 1.1 National Income, Population and Per Capita Income, 1972-73 to 1981-82.

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82 (Provisional)
	(in millions of rupees at constant factor cost of 1959-60)									
Gross Domestic Product (GDP)	35179	37901	39393	40699	41727	44805	47002	50423	53497	57045
Gross National Product (GNP)	35360	38085	39651	41410	43022	47480	50068	53575	56321	59636
Agriculture's Contribution to GNP	12821	13357	13074	13659	13998	14364	14861	15859	16493	17160
- Major Crops	7473	7844	7455	7833	7944	8115	8315	9105	9489	9878
- Minor Crops	1478	1585	1679	1839	1920	1962	2023	2085	2125	2190
- Livestock	3651	3724	3799	3875	3993	4129	4281	4441	4616	4806
- Fishing	128	115	82	86	96	100	148	137	170	193
- Forestry	91	89	59	26	45	58	94	90	93	93
	(percent)									
Percentage Agriculture GNP to total GNP	36.4	35.2	33.2	33.6	33.5	32.1	31.6	31.5	30.1	30.1
	(in millions)									
Population	65.24	67.20	69.21	71.29	73.43	75.63	77.90	80.23	82.60	85.0
	(in rupees)									
Per Capita Gross Income	542	567	573	581	586	628	643	668	682	702

Source: Pakistan Economic Survey, 1981-82, GOP, Finance Division, Economic Advisors Wing, Islamabad.

Table 1.2 Foreign Trade and Current Account Figures, 1975-76 to 1980-81.

	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81
	(million rupees)					
Foreign Trade						
Total Exports	11,253	11,294	12,980	16,925	23,410	29,280
Total Imports	20,463	23,012	27,815	36,388	46,929	53,544
Trade Balance	- 9,212	-11,718	-14,834	-19,463	-23,519	-24,264
Balance of Payments						
Balance on Current Account	- 8,177	- 8,934	- 4,838	-11,147	-11,336	- 9,811
Agricultural Exports						
Rice	2,479	2,478	2,409	3,380	4,179	5,602
Raw Cotton	909	292	1,094	655	3,321	5,203
Other	1,998	2,270	2,238	3,286	3,816	3,333
Total	5,386	5,040	5,741	7,321	11,316	14,138
Agricultural Exports as Percentage of Total	(percent)					
Rice	22.0	21.9	18.6	20.0	17.9	19.1
Raw Cotton	8.1	2.6	8.4	3.9	14.2	17.8
Other	17.8	20.1	17.2	19.4	16.3	11.4
Total	47.9	44.6	44.2	43.3	48.3	48.3
Agriculturally Based Commodity Exports	(million rupees)					
Cotton Yarn	1,422	1,172	1,060	1,956	2,038	2,050
Cotton Cloth	1,359	1,603	1,741	2,135	2,416	2,390
Carpets	719	912	1,171	1,765	2,198	2,243
Leather	596	647	637	1,247	1,264	892
Agricultural Imports						
Vegetable oil	1,047	1,478	1,553	2,953	2,295	2,625
Wheat	1,785	660	1,337	3,504	1,041	633
Other	1,892	2,077	3,008	2,942	3,667	4,606
Total	4,724	4,215	5,898	9,399	7,003	7,864
Agricultural Imports as Percentage of Total	(percent)					
Vegetable oil	5.1	6.4	5.6	8.1	4.9	4.9
Wheat	8.7	2.9	4.8	9.6	2.2	1.2
Other	9.2	9.0	10.8	8.1	7.8	8.6
Total	23.1	18.3	21.2	25.8	14.9	14.7

Source: Pakistan Economic Survey, 1981-82 GOP, Finance Division, Economic Advisors Wing, Islamabad. Foreign Trade Statistics, GOP.

Table 1.3 Vegetable Oil and Wheat Imports and Production, 1973-74 to 1981-82, Pakistan

Year	Vegetable Oil 1/			Wheat 2/		
	Imports	Production	Total	Imports	Production	Total
	(thousand tonnes)					
1973-74	243	167	410	1053	7629	8682
1974-75	220	194	414	1617	7674	9291
1975-76	176	267	443	1044	8691	9735
1976-77	178	285	463	346	9144	9490
1977-78	209	299	508	1052	8367	9419
1978-79	251	312	563	1958	9950	11908
1979-80	195	405	600	554	10857	11411
1980-81	203	460	663	96	11473	11569
1981-82	233	465	698	--	--	--

Source: 1/ Aide Memoire on Pakistan's Requirements of Edible Oils and Fats, found in Volume I, Edible Oilseeds Study, Office of International Cooperation and Development, U.S. Department of Agriculture, Islamabad office.

2/ Agricultural Statistics of Pakistan, GOP, 1981.

are annually imported. The major agricultural imports are vegetable oils and wheat and represent 4.9 percent and 1.2 percent of the total value of imports in 1980-81 (Table 1.3). In the case of wheat, both the value and quantity of imports have declined sharply in the past few years as a result of Pakistan's good wheat crops (Table 1.3). However, as the result of the rust epidemic in 1978, Pakistan was forced to import the largest quantity of wheat in its history. This resulted in the value of wheat imports being 9.6 percent of the value of total imports and adding to the negative trade balance.

Three sources of demand exist for Pakistan's agricultural output. The first source is Pakistan's population of 85.7 million (1982 estimate) which is growing at an annual rate of 3 percent and will continue to grow at this rate for some time. A second source of demand for agricultural output is the rising per capita income of the population. The third source of demand is for exports.

The 1981-82 real per capita gross income in Pakistan (Table 1.1) has increased by 30 percent over 1972-73 and is growing at an annual rate of about 3 percent. Rising incomes create a demand for more goods and services including agricultural products. An increase in agricultural output is required to meet the demand for better nutritional standards in Pakistan. Pakistan's daily per capita intake of 2255 calories and 62.0 grams of protein is less than the average world daily per capita intake of 2590 calories and 69.3 grams of protein and substantially lower than the North and Central American average intake of 3215 calories and 92.7 grams of protein (FAO Production Yearbook,

1979). Pakistan's agricultural output will be called upon to close the nutritional gap.

Rising incomes also change tastes and preferences. Rising per capita income in a country like Pakistan is always associated with a rising demand for vegetable oils and livestock products. Vegetable oil demand in Pakistan has risen from 410 thousand tons in 1973-74 to 698 thousand tons in 1981-82 which represents a 70 percent increase (Table 1.3). Demand projections for vegetable oils in 1991-92 are forecasted to be between 908 and 1239 thousand tons (Tabor, 1983). Domestic supply projections in 1991-92 are forecasted to be between 263 and 333 thousand tons (Tabor, 1983). Unless ways can be found to increase domestic production at a greater pace, the deficit will have to be made up for by increased imports adding to the existing negative trade balance.

Rising incomes have increased the demand for livestock products, in particular, poultry meats. Demand projections for poultry meat in 1990 forecast that 47 million broilers will be demanded, which is a substantial increase over the 1980-81 broiler production of 18 million (Cook, 1983).

The third source of demand for Pakistan's agricultural products is the export market. As previously noted, agricultural exports, in particular rice and cotton, are an important source of foreign exchange earnings.

Pakistan's increasing population, the desire for improved nutritional standards fostered by rising incomes and the increasing depen-

dence on raw and processed agricultural products as a source of foreign exchange puts a heavy demand on the agricultural sector. To meet this demand would require total agricultural output to grow at rates of 4 to 5 percent or better to avoid large food import bills and balance of payments problems. However, the problem arises in that Pakistan's agricultural crop output growth rate is less than the required 4 to 5 percent. The annual growth rate of all crops which includes both food and fiber crops is around 3.5 percent for the period 1973-74 to 1981-82 (Table 1.4).

The growth rates of the livestock sector have fared somewhat better. The growth rates for all meat production is 4.9 percent. The growth rates for mutton and poultry are 8.5 and 15.4 percent respectively. However, beef meat production which accounts for 45 percent of all meat production only grew at a rate of 1.2 percent (Table 1.4). Even at the present growth rates, the poultry industry for example, could not meet the projected demand for poultry meats. Any acceleration of the growth rates in any of the livestock categories would also require an accelerated growth rate in agricultural crop output for feed use well above the present 3.5 percent crop production growth rate.

In summary, Pakistan's agricultural sector is a dominant force in its economy. The fortunes of the agricultural sector can influence the wellbeing of other sectors such as manufacturing, construction, transport, wholesale and retail trade and the service sector. The exports and imports of raw and manufactured agricultural products

Table 1.4 Food Crop Production Index and Meat Production, 1973-74 to 1981-82.

	Food Crops Production Index	Meat Production			
		Beef	Mutton	Poultry	Total
		- - - - - (thousand tonnes) - - - - - -			
1973-74	196	354	245	19	618
1974-75	187	357	265	22	644
1975-76	199	362	288	25	675
1976-77	203	366	314	29	709
1977-78	209	370	339	33	742
1978-79	219	375	368	39	782
1979-80	239	379	399	45	823
1980-81	249	384	433	52	869
1981-82	258	--	--	--	--
Compound Growth Rates	3.5	1.2	8.5	15.4	4.9

Source: Agricultural Statistics of Pakistan, GOP, 1981.

heavily influence the trade balance which in turn affects the balance of payments. Pakistan's negative balance on the current account (Table 1.2) must be made up for by loans and foreign aid. Therefore, efforts must be made to not only maintain a healthy agricultural sector but also to strengthen it by providing an environment in which the sectors full potential is realized. The prominent position that agriculture plays in Pakistan's economy makes agriculture a focal point around which programs can be built to foster economic growth and development of the country.

1.2 Objectives

The growth in agricultural output and productivity is fundamental to the economic development of developing countries. In most developing countries, like Pakistan, the bulk of the country's resources are in the agricultural sector. The process of development is aided by using the savings from the agricultural sector to reinvest in agriculture as well as to invest in other sectors of the economy. The savings in the agricultural sector are brought about through the growth in agricultural output and productivity. The growth in agricultural output and productivity is a function of the agricultural development model which a country pursues and the commitment to which it is pursued.

The purpose of this study is to look at the agricultural development model of Pakistan, describe it and its environment and appraise its effectiveness in terms of the rate of return it produces from the investments made in its agricultural research and extension system.

The specific objectives of the study are:

i) to describe the Pakistani agricultural research and extension system and the environment within which it operates,

ii) to determine the overall rate of return to the Pakistani agricultural research and extension system and compare the rate of return to returns from other agricultural research and extension systems, and

iii) to determine the benefits, rates of return and to the extent possible, the distributional effects from investments in High Yielding Variety (HYV) wheat and maize crops in Pakistan.

1.3 Organization of the Study

Chapter 2 of the study first discusses in general form several models of agricultural development and then describes the Pakistan Agricultural research and extension system, its environment and its direction. Chapter 3 concentrates on describing the index number approach methodology and uses it to estimate the benefits and distributional effects from Pakistan's investments in HYV wheat and maize varieties. Rates of return for both wheat and maize are then calculated relating the estimated benefits calculated in the chapter to th research and extension expenditures invested in each crop. Chapter 4 outlines the use of a productivity model that is used to estimate the rate of return to the overall Pakistani investments in the research and extension system. Chapter 5 is a summary and discussion of the study.

Chapter 2

Pakistan's Agricultural Development Model

This chapter has several purposes. Although the main thrust of this study is to estimate the rates of return to the investments made in the Pakistan agricultural research and extension system, a second purpose is to describe the circumstances within which these returns (or losses) take place. To be able to better describe these circumstances, the first thing that is done is to describe in a very general way some agricultural development models. Secondly, the Pakistan agricultural research and extension system is described and thirdly, the research and extension systems experiences and environment are described and related back to the discussion on agricultural development models.

2.1 Models of Agricultural Development

Agriculture development throughout history has taken various forms each with different sources of growth and different agricultural output growth rates. A review of several agricultural models will help set the stage for thinking about the agricultural development strategies that Pakistan is pursuing.[1/]

2.1.1 The frontier Model

The frontier model of agricultural development has represented the main development strategy throughout history. Agricultural production is increased by the opening up and use of new and fertile

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1/ The thoughts and ideas expressed in section 2.1 rely heavily on Ruttan (1982).

tracts of land with little change in the existing technology of the day. When the increasing population of a village put pressure on the ability of the present agricultural lands to feed them, either more land would be brought into cultivation around the village or part of the population would move to virgin lands. A more dramatic example is the opening up of new lands in Australia and the Americas.

The frontier model is an inappropriate model for Pakistan to follow because little frontier land still exists. Even though there exist large areas of cultivatable waste lands in Pakistan, these lands require large capital inputs and new technologies to make them productive.

2.1.2 The Conservation Agricultural Model

The conservation model arises out of the European experience of the intensification of crop and livestock production. With land resources virtually fixed, agricultural output per unit of land was increased by increasing soil fertility through the use of green manure crops and animal manure. The intensification of crop and livestock production was facilitated by better use of water resources and labor, the use of animal power and the use of equipment. Most of these inputs were produced within the agricultural sector and often from the individual farm itself.

The conservation model is also inappropriate as an agricultural development model for Pakistan. The model is capable of sustaining growth rates of around 1 percent per year which is far from Pakistan's desired annual growth rate.

2.1.3 A Science-Based Agricultural Model

The frontier and conservation agricultural models are natural resource based agricultural models.[2/] Their contribution to agricultural productivity throughout history has been significant although todays demands on agricultural output make the models inappropriate. A more appropriate model to follow is a science-based agricultural model which is followed by all developed countries and is now followed by most developing countries including Pakistan but with various degrees of commitment and success.

Science-based agriculture focuses on three main areas:

1) The use of high-payoff inputs
2) The development of efficient technologies consistent with a country's resource endowments
3) Institutional development that facilitates both 1) and 2).

The first category of high-payoff inputs which follow the high-payoff input model of Schultz (1964) are classified broadly as follows (Ruttan, 1982, p. 25):

1) The capacity of public and private research institutions to produce new technical knowledge

2) The capacity of the industrial sector to develop, produce and market new technical inputs

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2/ In addition to the frontier and conservation models described in this section, Ruttan (1982, p. 20) describes the urban-industrial impact model, the diffusion model, the high-payoff input model and the induced innovation model. The science-based agricultural model as described in this section draws from the ideas and concepts of these models.

3) The capacity of farmers to acquire new knowledge and to use new inputs effectively.

In the second category, the development of efficient technologies consistent with a country's resource endowments means that technologies be developed with a country's particular resource price ratios in mind. That is, in a country such as Pakistan, where labor is cheap relative to other inputs, the agricultural education, research and extension system must produce technologies to exploit the use of this relatively cheaper input. Attention to resource price ratios will ensure that an appropriate path of technological development is followed that will permit an optimum agricultural output response. Implicit in the science-based agricultural model and the development of efficient technologies is that agricultural technology is "location specific" and that advanced technology developed in other countries or even in other areas of the same country may not be directly transferable.

Institutional development in the science-based agricultural model encompasses the development of those institutions that directly influence agriculture output and productivity. The most visible institutions are the agricultural education, research and extension component along with the input and product market institutions.

The basic units of the agricultural education, research and extension component are the university's and agricultural technical schools, research stations and research institutes and the extension departments. Institutional development here refers to the organiza-

tion of each of the units along lines as dictated by the management sciences so that resoucces and manpower are used effectively and efficiently. This includes proper incentive mechanisms for scientists, educators, extension specialists and administrators and a system of financial support with the control, timing and allocation of funds conducive to work being done on significant problems in agriculture. Institutional development of agricultural education, research and extension also calls for the direct linkages between the three areas so that new technologies are both appropriate and transferred as rapidly as possible.

Institutional development in science-based agriculture also includes the development of input and product markets. The inputs used in the frontier and conservation models were acquired on the farm or within the agricultural sector. Most of the inputs required by a science-based agricultural model come from the non-agricultural sector and therefore, require resources to be devoted to the organization of a marketing system. High yielding varieties, fertilizer, pesticides, mechanical power and credit all have to be purchased from the non-agricultural sector and be available at specified times and quantities. Institutional development must also take place in the product markets as the demand for marketing services increases with a rural to urban population shift and more products move through wholesale and retail channels (Hayami and Ruttan, 1971, p. 268).

The social sciences, in particular economics, provide the guidelines for the development of the structure of the input and product

marketing institutions that are consistent with increased agricultural output and productivity growth.

In summary, the science-based agricultural model of development requires a strong integrated agricultural education, research and extension system. Science-based agriculture relies on the physical and biological sciences, management sciences and social sciences to produce and disseminate new technologies and guide institutional development that will provide the proper environment for optimum agricultural output and productivity growth. Evidence exists that productivity growth and the rate of return from employing a science-based agricultural model are high. The United States experience, the experience of other developed nations and the high rates of return to investment in science-based agriculture indicate that this model of agricultural development has the potential to attain agricultural output growth rates required by developing nations.[3/]

2.2 Pakistan's Agricultural Research and Extension System

Pakistan has followed a science-based agricultural tradition that extends into the British period of its history. The University at Faisalabad (Lyallpur) began in 1909 and was an international model of agricultural education and research. The heart of the science-based agricultural system, that of the agricultural education, research and

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3/ Ruttan (1982, p. 242) and Pinstrup-Anderson (1982, p. 102) summarize the various studies on rates of return to agricultural research and extension. Most of the studies indicate a high rate of return; higher than the 10-15 percent (above inflation) rate of return required by private investment firms in the private sector.

extension component does exist in Pakistan today. At present there are 65 agricultural education and research institutes in the country which control 162 research stations, substations, centers, sub-centers and laboratories (Wahid, 1982, p. 95). Each of the four provinces has an Extension Department. Pakistan was one of the key green revolution countries adopting the high yielding varieties of maize, wheat and rice and the associated packages of technology.

As noted above, there exists a very large number of research institutes. The research institutes and organizations involved in Pakistani agricultural research derive their authority and funding from either the central Government or one of the four Provincial Governments.[4/] The major agricultural research organizations are given by ISNAR (1983) as follows:

Central Institutes

- Pakistan Agricultural Research Council (PARC)
- Atomic Energy Agency
- Water and Power Development Authority (WAPDA)
- Pakistan Science Foundation
- Pakistan Central Cotton Committee (PCCC)
- Pakistan Tobacco Board
- Pakistan Forest Research Institute

Provincial Institutes

- Agricultural Research Institutes
- Agricultural Universities

4/ The description of the Pakistan agricultural and research system in this section is based on the knowledge gained while the author was in Pakistan as well as on several good reports on the subject such as Amir Muhammed (1982), National Science Council of Pakistan (1982), Wahid (1982) and a very good description by ISNAR (1983).

Interfaced with many of the institutes are the international research centers such as the International Center for Improvement of Maize and Wheat (CIMMYT) and the International Rice Research Institute (IRRI) which are the most noticable and have ongoing programs within Pakistan.

The 1947 independence partition left Pakistan without any established institutions intact. The authority over agriculture research and extension went to the Provinces with little authority or resources given to the central organization of the federal government. The central organization is now called the Pakistan Agricultural Research Council (PARC) after going through several name changes and reorganizations since 1947. The role played by PARC today is stronger and more important than its predecessors. PARC under its 1981 charter performs a coordinating role and provides funding for foreign technical assistance, foreign training of both federal and provincial personnel and procurement of equipment. A substantial portion of the development budget comes in the form of foreign exchange and is not available for incountry expenditure.

The coordinated programs of PARC come under the name of National Coordinated Programs (NCPs). There are twelve NCPs, some on a commodity basis like wheat, rice, maize and sugarcane with other NCPs on an area basis like oilseeds. Most of the national coordinators of NCPs are located at the National Agricultural Research Center (NARC) in Islamabad which is a research station. The goal of NARC is to conduct research and provide leadership in areas of national importance

where research is not now being conducted by the provinces. The NARC also provides facilities for training, laboratories, libraries and technical staff available for use by other institutions and a social science staff familiar with Farming Systems research as well as being the national show case for Pakistan. At the time of writing, the NARC building site was almost complete and all departments not fully staffed. NARC also supports the Arid Zone Agricultural Research Institute (AZRI) in Quetta.

The Atomic Energy Agency has two facilities in operation and one being built in the N.W.F.P. The Atomic Energy Agricultural Research Center (AEARC) in Tandojam, Sind was started in 1960 and the National Institute of Agriculture and Biology (NIAB), Faisalabad was formed in 1974. To date, no major varieties from these institutions have been widely adopted by producers.

The Water And Power Development Authority (WAPDA) does most of the research in Pakistan on irrigation systems. The Pakistan Science Foundation funds small grants to scientists. The Pakistan Tobacco Board and the Pakistan Forest Research Institute provide the research in their own areas.

The Pakistan Central Cotton Committee (PCCC) is the only agricultural food and fiber crop exclusively controlled outside PARC and Provincial institutes. The PCCC is responsible for research not only in the agronomic and genetic areas but throughout the entire cotton industry which includes the marketing, promotion, processing and manufacturing areas. The PCCC is supported by a cotton cess (levy) on

marketed cotton. Based in Karachi, much of the research is done in stations at Multan and Sakrand. Although not on the same scale, Provincial institutes do some genetic and agronomic research as well.

The Provincial agricultural research institutes and their substations in each of the four provinces derive their authority and funding through the Provincial agricultural ministries. These research institutes form the bulk of the agricultural research capabilities in Pakistan. The institutes are located in Faisalabad (Punjab), Tandojam (Sind), Peshawar/Pirsabak (N.W.F.P.) and Quetta (Baluchistan).

Three agricultural universities exist in Pakistan at Faisalabad, Tandojam and Peshawar. The universities are autonomous bodies which are Provincial in character but deriving their funds through the University Grants Commission which allocates funds given by the central government through the ministry of education. The Universities constitute the largest body of scientific manpower with advanced academic training (ISNAR, 1983). However, the role of the Universities are largely as teaching institutions and not research or extension institutions. The three universities produced 1090, 510 and 5 graduates with B.Sc., M.Sc. and Ph.D. degrees respectively in 1980-81 (ISNAR, 1983).

Prior to 1961, the University of Faisalabad (then Lyallpur) housed both the teaching and the provincial research capabilities. Subsequent to 1961 the teaching and research components were split into the present day institutions. The universities at Tandojam and Peshawar as well as the Sind and N.W.F.P. research institutes were

established on the model of the split teaching-research institutes in the Punjab. There are those who express the idea that it is time to once again merge the teaching and research institutes so that there is a more integrated research and teaching effort.

The agricultural extension system of Pakistan is set up on a provincial basis. Each province has an agricultural Extension Department which receives its funding and authority from their respective provincial governments. The departments are set up in the usual way with the focal point being the field personnel responsible for a certain geographical area within a district. Field personnel in the past did not require much training beyond the high school stage however now, training is provided for one or two years by most departments. The Training and Visit system (T & V) which utilizes a more concentrated approach to extension has been initiated in some of the districts in the Punjab but as yet is not wide spread. Some extension is carried out by research institutes and PARC through field days and yield constraint and other farm trials.

2.3 Pakistan's Experience with Science-Based Agriculture

The Science-based agricultural model has worked to Pakistan's advantage. Science-based agriculture has helped Pakistan achieve the 3.5 percent growth rate in crop production and the growth rates achieved in meat production as shown in Table 1.4. However, Pakistan must not only sustain its present agricultural production growth rate but attain a higher growth rate if it is to avoid large food import

Table 2.1 Yields of Major Crops by Continents and Selected Countries, 1980.

	Wheat	Rice (Paddy)	Sugar Cane	Cotton (Seed)	Maize
			(kg/ha)		
World	1873	2750	55671	1270	2995
Africa	1041	1714	64920	888	1222
North and Central America	2125	4034	57647	1378	4734*
South America	1297	1915	59330	939	1846
Asia	1631	2800	48850	1004	2242
Europe	3764	4890	67000	2139	4483
Egypt	3225	5752*	84060*	2675*	4029
Turkey	1896	—	—	1892	2263
Mexico	3618*	—	—	1323	1295
Japan	3052	5128	65764	NA	3000
India	1437	2049	48310	525	1103
Pakistan	1563	2400	38189	1002	1365

* Represents the highest yield.

Source: FAO Production Year Book, 1980, Vol. 34.

bills and balance of payments problems.

Although Pakistan's Science-based agricultural model has had achievements, it has not been a complete success. Table 2.1 indicates that the yields of the major crops in Pakistan lag behind the world averages and are one-half the yield of those countries that have realized the best farm yields. Studies in Pakistan show that a substantial yield gap exists between the potential farm yield and the actual farm yield and that On-Farm Yield Constraint Trial data indicates that Pakistan can approach the farm yields of those countries that have realized the best yields as presented in Table 2.1 (PARC, 1981). Similarly, in the livestock sector, milk production per animal and feed conversion to meat production are very low and a similar gap exists between the potential and actual farm production levels.

The constraints preventing the narrowing of the yield gap are both biological and socioeconomic. Gomez et al (1979) define the biological constraints as variety, weeds, diseases and insects, problem soils, water and soil fertility. They define the socioeconomic constraints as costs and returns, credit, traditions and attitudes, knowledge, input availability and institutions. A well designed science-based agricultural system must deal with these constraints. It is clear that the science-based agricultural model in Pakistan has failed to remove and narrow the major constraints to increased agricultural output in both crop and livestock production. The fault however, does not entirely lie with a science-based agricultural model approach but rather with its implementation.

It is possible in a general way to point out several key indicators as to why science-based agriculture in Pakistan is not as successful as it might be. The deficiency in the implementation of a science-based agriculture in Pakistan can be found in the three key areas of the research system, the extension system and the input and product market institutions.

2.3.1 The Agricultural Research System

Two key indicators as to why the agricultural research system of Pakistan's science-based agricultural model has not risen to its full potential is the history of its funding and its scientific staffing situation.

Table 2.2 indicates that Pakistan's expenditure on total research and development in 1980 was 0.14 percent of GNP and is the lowest of all the countries included in the table. Although the expenditures presented in table 2.2 are total expenditures in addition to agricultural research, it does indicate the support and attitude of research and development in Pakistan.

Table 2.3 presents agricultural research and development expenditures as a percentage of agriculture's contribution to GNP for Pakistan and the United States in 1978. It will be noted that Pakistan's expenditure on agricultural research as a percentage of GNP is one-quarter that of the United States while agriculture's contribution to GNP in the United States was 3.1 percent while it was 29.3 percent in Pakistan.

Table 2.2 Expenditure on Research and Development as % of GNP, Selected Countries

Africa		
Egypt	(1973)	0.8
Ghana	(1976)	0.9
Kenya	(1975)	0.8
Madagascar	(1971)	0.9
North America		
Canada	(1977)	1.1
U.S.A.	(1979)	2.3
South America		
Argentina	(1980)	0.9
Brazil	(1978)	0.6
Asia		
India	(1977)	0.5
Iran	(1974)	0.3
Israel	(1978)	2.5
Japan	(1979)	2.1
Korea	(1979)	0.6
Turkey	(1979)	0.6
Pakistan	(1980)	0.14
Europe		
Belgium	(1977)	1.4
Bulgaria	(1978)	2.2
Chechoslovakia	(1978)	4.2
Denmark	(1979)	1.0
Finland	(1979)	1.1
France	(1977)	1.8
Germany Fed. Rep.	(1977)	2.1
Hungary	(1979)	3.2
Netherlands	(1978)	2.0
Norway	(1978)	1.5
Celani	(1975)	0.8
Switzerland	(1977)	2.2
United Kingdom	(1975)	2.1
Yugoslavia	(1978)	1.1
Oceania		
Australia	(1976)	1.0
New Zealand	(1975)	0.9
USSR	(1979)	4.9

Source: UNESCO Year Book, 1981.

Table 2.3 Agricultural Research Expenditures as a Percentage of Agriculture's Share of GNP, USA and Pakistan, 1978.

	United States (million USA $)	Pakistan (million rupees)
Total GNP	2,127,600 1/	169,310 3/
Agriculture's Contribution to GNP	66,600 1/	49,522 3/
Percentage of Agriculture GNP to Total GNP	3.1%	29.3%
Expenditure on Agricultural Research	1,147.4 2	195.8 4/
Research Expenditures as % of Agriculture GNP	1.7%	0.4%

Sources: 1/ Statistical Abstract of the United States, 1980, U.S. Department of Commerce.
2/ Ruttan, V.W., Agricultural Research Policy, University of Minnesota Press, 1982.
3/ Pakistan Basic Facts, 1980-81, GOP, Finance Division.
4/ Appendix B, Table B-3.

Table 2.4 Number of Agricultural Scientists Compared to Population, Selected Countries

Country	Agricultural Scientists Per 10,000 Population
United Kingdom	44.2
Japan	35.4
U.S.A.	25.2
West Germany	16.8
France	12.4
Egypt	3.0
India	1.7
Pakistan	0.4

Source: UNESCO Year Book, 1980.

Table 2.4 indicates that Pakistan has a very low agricultural scientist to population ratio in relation to the developed countries that support a science-based agricultural system. The total scientific manpower engaged in Pakistan's agricultural research in 1977-78 was 3,169. Of the 3,169 research scientists, 250 held a Ph.D., 1,637 held a M.Sc. and 1,282 a B.Sc. degree. Thus, 8 percent held a Ph.D. and is low compared to the 80 percent of the scientific manpower that held a Ph.D. in the U.K. agricultural research system (Wahid, 1982). Since 1977-78, training has been stepped up through PARC, however there still remains a gap in the number of trained scientists required.

It may be unfair to compare Pakistan's funding and scientific staff requirements to that of a premier research system like that of the USA or to some of the other developed countries. Pakistan's funding and staffing requirements may well be less in relation to the premier research institutions in order to be effective particularly when they have the support from international research institutions. While this may be true, the levels of funding and staffing appear to be too low according to a report of a reconnissance team on the agricultural research system of Pakistan by Pray et al (1982). The report suggests that low funding levels and scientific staff shortages lead to and compound the problems of the research system. Among their findings were that the linkages between agricultural education, research, extension and agro-industry is very weak. Capital items such as farm machinery, laboratory equipment and library facilities were seriously

inadequate. They also found that scientific staff numbers at the Ph.D. and M.Sc. levels were inadequate and that a poor salary structure exists along with a general lack of an environment conducive to proper research and teaching. They also noted that managerial skills were lacking at all levels in the research system.

The wheat rust epidemic in 1977-78 and the gram blight epidemic in 1980-81 (See Appendix F for a full description) serve as two prime experiences where a full functioning science-based agriculture could have decreased the adverse economic impacts from decreased production. The system failed to use existing information available from its previous experiences and experiences from other countries. The estimated losses from the wheat rust epidemic were in the order of Rs. 1,157 million (U.S. $116.8 mil.) (see Appendix F). This amount is some 4.5 times the total funds expended in the entire Pakistan research and extension system in the same year.

2.3.2 The Extension Service

While Pakistan's conventional field assistant extension system is well developed on paper in the form of organizational charts, it is not clear that is has played a major role in the diffusion of new technology or increased productivity. In an extensive study, Lowdermilk (1972) found that extension contacts with Pakistani farmers were statistically not significant with respect to 1) HYV wheat adoption (p. 213) and 2) the level of nitrogen use (p. 263). In a summary statement on extension (p. 350) he cites extremely low levels of contacts between farmers and extension personnel. Information sources

were mostly interpersonal such as neighbors, relatives and council members.

Low levels of contact between farmers and extension personnel are not of itself sufficient evidence to conclude that the extension system has little effect on increased productivity. Extension workers may be concentrating their efforts on fewer farmers but from which there is a flow of information to others. However, the following paragraph of Lowdermilk's may negate this premise.

> "It must be realized that he [field assistant] is ill-trained for problems of modernization of agriculture, provided almost no in-service training, has only very meager technical assistance by crop specialists, has far too high a farmer-extension ratio, has no housing, transportation facilities provided by the Department, is provided with little medical assistance, is paid a very small salary, has almost no opportunities for advancement through further training, is poorly supervised, provided few incentives and little motivation for improvement, studies and reads very little for self improvement, has too much paper work and diary writing and is often the pawn moved and ordered around by a top-heavy bureaucracy. Many of the present F.A.s exhibit deficiencies in knowledge about the new varieties and most have difficulties in problem solving situations concerning recommendations to make farmers facing certain problems." (Lowdermilk, 1972, p. 362)

Although Lowdermilk's appraisal was written in 1972, contacts with extension people, research scientists and others lead me to believe that the extension system has not changed much in the intervening years. With the exception of the Training and Visit System (T & V) initiated recently in a few districts and new efforts to increase field assistant training, much of Lowdermilk's appraisal of the extension system holds true today.

A science-based agricultural system without a fully functioning extension system constraints the benefits that may accrue from the

research system. An extension system that does not provide a flow of information to the research system on the problems and needs of producers has also a constraining influence.

2.3.3 The Input and Product Market Environment

The input and product market environment within which the agricultural sector must operate is another key element of a science-base agricultural system. Input availability, input and product market efficiency and the relative input and product price ratios play a role.

There is a general immaturity of the markets that handle the inputs and credit required by science-based agriculture in Pakistan. The government is heavily involved in the logistics and handling of fertilizers, pesticides, herbicides, and the distribution of improved seeds. However, other than some improved seeds, these inputs are not used on a very large scale. Herbicides are virtually not used in Pakistan. In 1980-81, pesticides were used on 4.8 percent of the cropped area (Agricultural Statistics of Pakistan, 1981, pp. 130-131). Fertilizer consumption in Pakistan in 1979-80 was 51 kgs per hectare compared to 111 in the USA, 312 in France, 478 in Japan and 805 in the Netherlands (Agricultural Statistics of Pakistan, 1981, p. 125). The average 51 kgs/ha falls short of the recommended fertilizer levels by the directorate of soil fertility. In the case of wheat alone which comprises over a third of the cropped acreage in any given year, recommended (agronomic) application rates for irrigated wheat are

140-84 kg/ha of N and P and for the Barani area, 111-67 kg/ha of N and P. In a recent survey that asked farmers why they did not use fertilizer, lack of knowledge, lack of funds (credit) and desired fertilizers not timely available were the three principle reasons given (National Fertilizer Corporation of Pakistan, 1981, p. 27).

There is also a shortage of good quality seed for distribution. About 20 percent of wheat acreage is still sown to the older tall varieties of wheat (Table C-6).[5/] Of the 80 percent sown to HYV's, 75 percent is sown to varieties that are no longer recommended because of disease suceptibility.[6/]

In the product markets, the government is involved in the procurement of wheat (see Appendix E) and rice and sets procurement prices. On export commodities such as rice and cotton, an export tax is levied, The result is that for most of the domestic commodities, domestic prices are lower than border prices. In 1980-81, domestic prices as a percentage of border prices for wheat were 75%, seed cotton 95%, Bosmati Rice 61%, IRRI rice 50% and sugarcane 72%. At times cotton and sugarcane prices have been supported above the border price

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5/ This does indicate that an increased effort is required by the extension component, however, there are areas in Pakistan that required the seed to be planted at lower depths than normal to have access to moisture. In wheat, the length of the first shoot is proportional to the height of the plant and semi-dwarf varieties have difficulty emerging from the ground. Thus, tall varieties do better. This underscores the value of location specific varieties.

6/ Based on varietal surveys of the Punjab in 1981-82, 76 percent of the farmers used varieties that were not recommended (Punjab Ministry of Agriculture).

as in 1977-78 when they were at levels of 107% and 221% (World Bank, 1982).

The government has also subsidized inputs. Fertilizer has been the input subsidized the most and in 1980-81 was subsidized at 65 percent of the border price. However Gotsch and Brown (1980, p. 94) sum up government intervention in the input and product markets as follows:

> "Clearly the subsidies have gone mainly to consumers, and been paid for mostly by farmers through excise taxes and lower than free market prices. Taxes on rice and cotton alone have been substantially greater than total farm subsidies (excluding subsidized credit)... In addition, these taxes, export restriction and other measures have extracted an even larger'tax' from farmers in the form of lower than free market prices for commodities consumer. Within Pakistan ..., less than free market prices..., for wheat, for example, reduced farm income from marketed wheat by more than 10 times the amount of government subsidies that might reasonably be attributed to the benefits of wheat production, ..."

The price distortions caused by government intervention not only produce an imbalanced cropping pattern but may in part explain the low level use of science-based agricultural inputs. While input nonavailability is a major constraint, a maturer input market system may have developed had there been more demand through a higher product price-input price ratio. The social sciences, in particular economics, provide the guidelines for the development of the structure of the input and product marketing institutions that are consistent with increased agricultural output and productivity growth.

2.4 Summary and Discussion

The frontier or conservation agricultural development models are unlikely to provide the growth in output and productivity required by Pakistan in the future. A more promising agricultural development model is that of a science-based model relying on the natural sciences, management sciences and social sciences to produce and disseminate new technologies and guide institutional development. While Pakistan does follow a science-based agricultural model, it has met with less than complete success. The inability to fully commit the necessary resources, programs and effort to science-based agriculture has inhibited the further removal of biological and socioeconomic constraints that are present in the Pakistan agricultural system.

It is not the intention to suggest that a science-based agriculture can avoid each and every production emergency and crisis situation. However, it is suggested that science-based agriculture can minimize the effect of many situations. The effects of the gram blight and wheat rust epidemic could have been minimized. However, the Pakistan research and extension system failed to use existing information available from its and other countries' experiences.

Given the description of the environment that the Pakistan agricultural research and extension system finds itself, Chapters 3 and 4 now turn to estimating the rates of return to the agricultural research and extension system.

CHAPTER 3

Estimation of the Benefits, Welfare Distribution and Rate of Return To Wheat and Maize Research and Extension

3.1 Introduction

This chapter is concerned with arriving at rates of return to agricultural research and extension investments within Pakistan. The wheat and maize crops have been chosen for the analysis primarily because of; 1) their importance as the number one and number three staple crops respectively, 2) along with the rice crop, they have been the recipients of large research and extension budgets and are affiliated with international organizations, and 3) the availability of data necessary for the analysis.

The analysis will employ an index number approach to obtain the returns from research and extension investments. Section 3.2 presents an overview of the index number approach and the estimates of the benefits for wheat and maize are given in sections 3.3 and 3.4 respectively. Section 3.5 relates the benefits to the expenditures and calculates the rates of return. Section 3.6 presents some of the distributional effects from research and extension investments and section 3.7 ends with a summary and discussion.

3.2 An Overview of the Index Number Approach

The index number approach (consumer-producer surplus approach) estimates the benefits to agricultural research by measuring the change in consumer surplus (CS) and producer surplus (PS) from a rightward shift in the supply curve that has been brought about through technological change.

Given a perfectly competative industry, no import or export restrictions and marketable surplus equal to production, the change in CS and PS given a supply shift is demonstrated in figure 3.1. The pre-innovation supply curve S_0 shifts to the right to the post-innovation supply curve S_1 because of the adoption of a new technology (in this case, HYV seed). Thus the actual market situation is expressed by supply curve S_1 and demand curve d intersecting at the actual price P_1. S_0 on the otherhand represents the supply curve that would have existed had researchers not improved varieties or farmers not adopted them. The market situation would then be expressed by the intersection of S_0 and d resulting in price P_0.

The change in consumer welfare (CS) from the supply shift is represented by area P_0ABP_1. The change in CS is positive and represents a gain because of the drop in price from P_0 to P_1. The change in the producers welfare (PS) from the supply shift is represented by area GOB minus area P_0AGP_1. Area AOB is a gain to producers from a lower cost per unit of output and increased quantity marketed Q_0 to Q_1. Area P_0AGP_1 represents the loss to producers from the price fall from P_0 to P_1 and is zerro for a perfectly elastic demand curve and otherwise negative. PS may be either positive or negative and depends on the magnitudes of the supply and demand elasticities. However, highly elastic demand curves result in large P_0AGP_1 areas which invariably result in negative PS numbers.

Once CS and PS are calculated, the gross annual research benefits

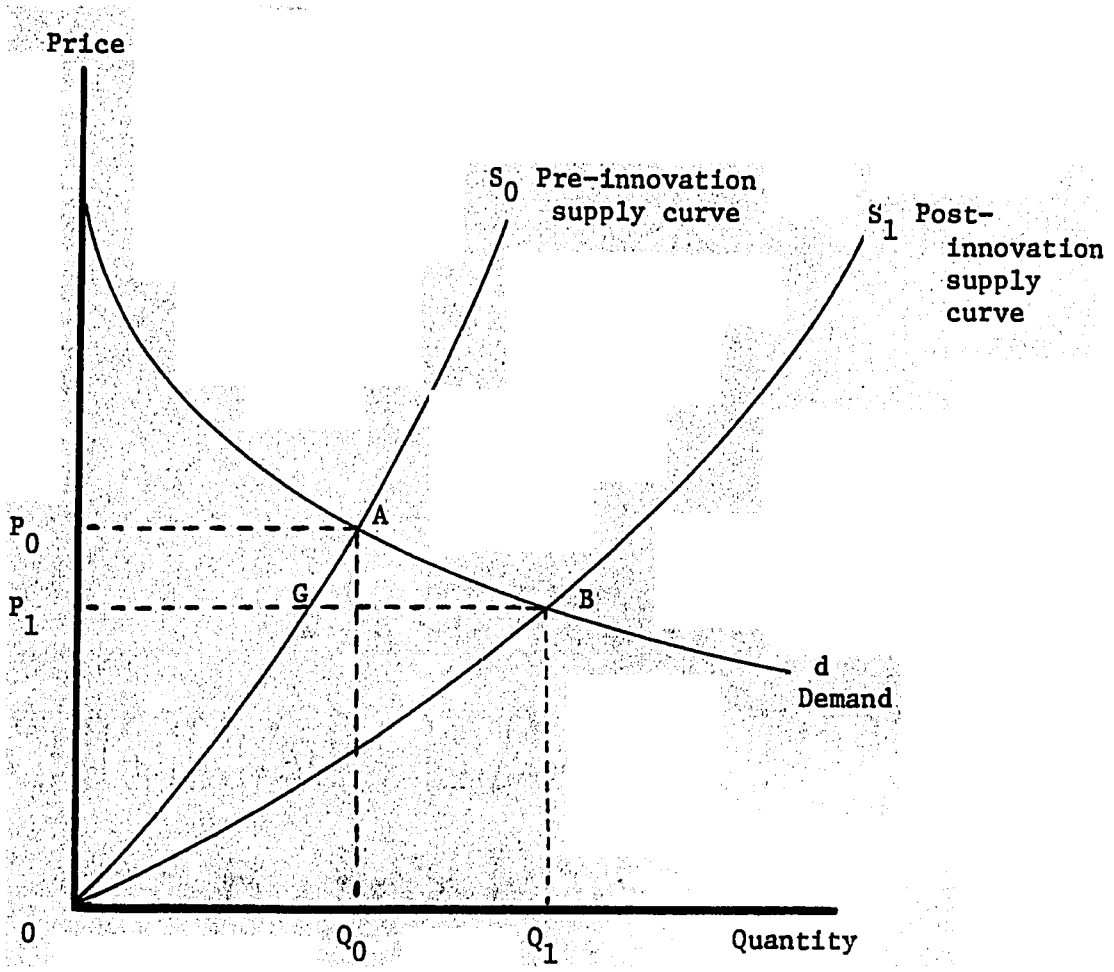

Figure 3.1 Model of Benefits from Crop Varietal Improvement

(GARB) can be calculated and is represented by area AOB.[1/]

Following Akino and Hayami (1974), Figure 3.1 can be mathematically expressed. A two dimensional constant elasticity demand function is assumed and represented annually by equation 3.1

$$q = HP^{-\eta} \tag{3.1}$$

where q is the quantity demanded, P is the price, η is the price elasticity of demand and H is a parameter representing the variables that influence the demand other than its own price. In the same manner, a two dimensional constant elasticity supply function is assumed as follows:

$$q = GP^{\gamma} \tag{3.2}$$

where q is the quantity supplied by producers, P is the price received by producers, γ is the price elasticity of supply, and G is a parameter representing the variables that influence the supply other than its own price.

The hypothetical supply function S_0 in Figure 3.1 is the supply function that would have existed had there been no research that developed new higher yielding varieties. Thus the assumption is made that S_0 is some percentage 'h' less than the actual supply function S_1 and is specified as follows:

$$q = (1 - h)GP^{\gamma} \tag{3.3}$$

where h is the percentage by which the current supply S_0 shifts left

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1/ To see that area AOB is equal to GARB, let A = Area P_0AGP_1, B = area ABG, and C = area GOB then: CS = A + B and PS = C + A. Therefore GARB = CS + PS = B + C because A is positive for CS and negative for PS.

if new varieties are replaced by old varieties in a given year.

Since the supply function in comparative statics is the marginal cost function derived from the production function, the rate of shift in the marginal cost function (h) is related to the rate of shift in the production function (k). The relationship between h and k is approximated as follows:2/

$$h \approx (1 + \gamma)k \tag{3.4}$$

Estimates of the annual benefits (GARB) may be calculated once the following data and information is made available: 1) supply and demand elasticities, 2) yearly price and quantity data, and 3) the annual leftward shift in the actual supply curve S_1 in order to establish the pre-innovation supply curve S_0 (usually called the supply shifter k). By substituting k, η, γ, P_1 and Q_1 into the following approximation formulas of Akino and Hayami (1974), annual estimates of PS, CS and GARB are obtained.3/

$$\text{area AGB} \approx \tfrac{1}{2}p_0q_0\frac{[k(1+\gamma)]^2}{\gamma+\eta}$$

$$\text{area GOB} \approx kp_0q_0$$

$$\text{area } P_0AGP_1 \approx \frac{p_0q_0k(1+\gamma)}{\gamma+\eta} \cdot \left[1 - \frac{\tfrac{1}{2}k(1+\gamma)\eta}{\gamma+\eta} - \tfrac{1}{2}k(1+\gamma)\right]$$

2/ k is traditionally know as the supply shifter as in the articles by Griliches (1958), Peterson (1967) and Ayer and Schuh (1972). However Akino and Hayami interpret k as a production function shifter. The mathematical derivation can be seen in the appendices to Hayami and Akino (1977 p. 52).

3/ The approximation formulas are derived with the assumption of a neutral shift in the aggregate production function. The mathematical derivation of the formulas are given in Hayami and Akino (1977).

where: $p_0 = OP_0$ and $q_0 = OQ_1$

Rate of return figures may then be calculated from the annual stream of benefits derived from the index number approach and the associated annual stream of research costs of the new technology.

The index number approach has gone through an evolution since the Griliches hybrid corn study in 1958. This "first generation" model used a unitary elastic demand curve and estimated returns for both a perfectly elastic and inelastic supply curve with a crude guesstimate of the supply shifter k. Although the model was crude, Griliches (1958), along with the pioneering work by Schultz (1953), started people thinking about the returns to research and led to "second generation" models that gave more attention to elasticities of supply and demand, estimation of expenditures, the shift parameter k and the change in the distribution of income from technological change. Among the early second generation models were a poultry study by Peterson (1967), a Brazilian cotton study by Ayer and Schuh (1972), the Akino and Hayami (1974) study on rice in Japan as previously noted and the Schmitz and Seckler (1970) tomato harvester study.

Two studies in particular, that of Scobie and Posada (1977) and Hayami and Herdt (1977) brought the income distribution analysis further than the earlier models. The Scobie and Posada model looked at CS and PS disaggregated by income levels and farm size as well as between irrigated and non-irrigated producers. The Hayami and Herdt model disaggregated producers into small and large producers and added a home consumption demand. A home consumption demand was added

because marketable surplus does not equal production for rice in the Philippines, rather home consumption plus marketable surplus equals production. Following up the Akino-Hayami and the Hayami-Herdt models, Nguyen (1977) extends the models to include a ceiling price. A study by Evenson et al (1977) in a similar vain includes a target domestic price in the analysis.

Evenson (1980) takes the concept of measuring benefits from research a step further by introducing duality models with a system of output supply and input demand functions. Changes in the supply of a commodity from the adoption of new technology can then be traced throughout the agricultural sector.

Several good literature reviews exist on the state of the art of the index number approach. These include Schuh and Tollini (1978), Scobie (1979), Norton and Davis (1981) and Zentner (1982). A list of rate of return studies using the index number approach and their associated rate of return figures are available in Ruttan (1982, p. 242) and Pinstrup-Anderson (1982, p. 102).

3.3 Estimates of the Benefits from Wheat Research and Extension

The perfectly competitive, free trade, marketable surplus equal production model in Figure 3.1 will have to be altered for the case of wheat in Pakistan. First, a sizeable portion of wheat production is used in home consumption. The 1960 Pakistan Census of Agriculture reported that marketed production represented 34 percent of total production whereas the 1981 survey by the Agricultural Prices Commission

(1981) estimated that 60 percent of total production was marketable surplus. With the increase in both wheat yield per hectare and hectares sown to wheat, the marketable surplus would have risen since 1960 however it may be slightly lower than the 60 percent survey figure owing to the nature of the survey.4/

Secondly, the price is altered by two government interventions in the wheat market. These are imports and a domestic wheat procurement program. The wheat pricing and marketing system is described and discussed in Appendix E.

Figure 3.2 depicts the modified model. The wheat price P_2, through government intervention lies below the equilibrium price after technological change.5/ The total quantity available Q_2 is made up of domestic production OQ_0 and imports Q_0Q_2. The home consumption demand curve is depicted by D_hH.

In the absence of the adoption of HYV's by producers, S_0 becomes the relavent supply curve. If it were assumed that no government intervention took place, then the price P_0 would reign and ΔCS, ΔPS and GARB would be calculated in a similar manner as that of maize in section 3.4 of this chapter. However given that there was government intervention in the post HYV adoption periods, there certainly would

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4/ The survey was conducted in predominantly surplus wheat areas.

5/ Domestic procurement programs generally suggest a price support system. However, in the case of Pakistan, the procurement system is neutral at best. The combination of the procurement and import policies suggest a price below the equilibrium price after technological change, (see Appendix E.)

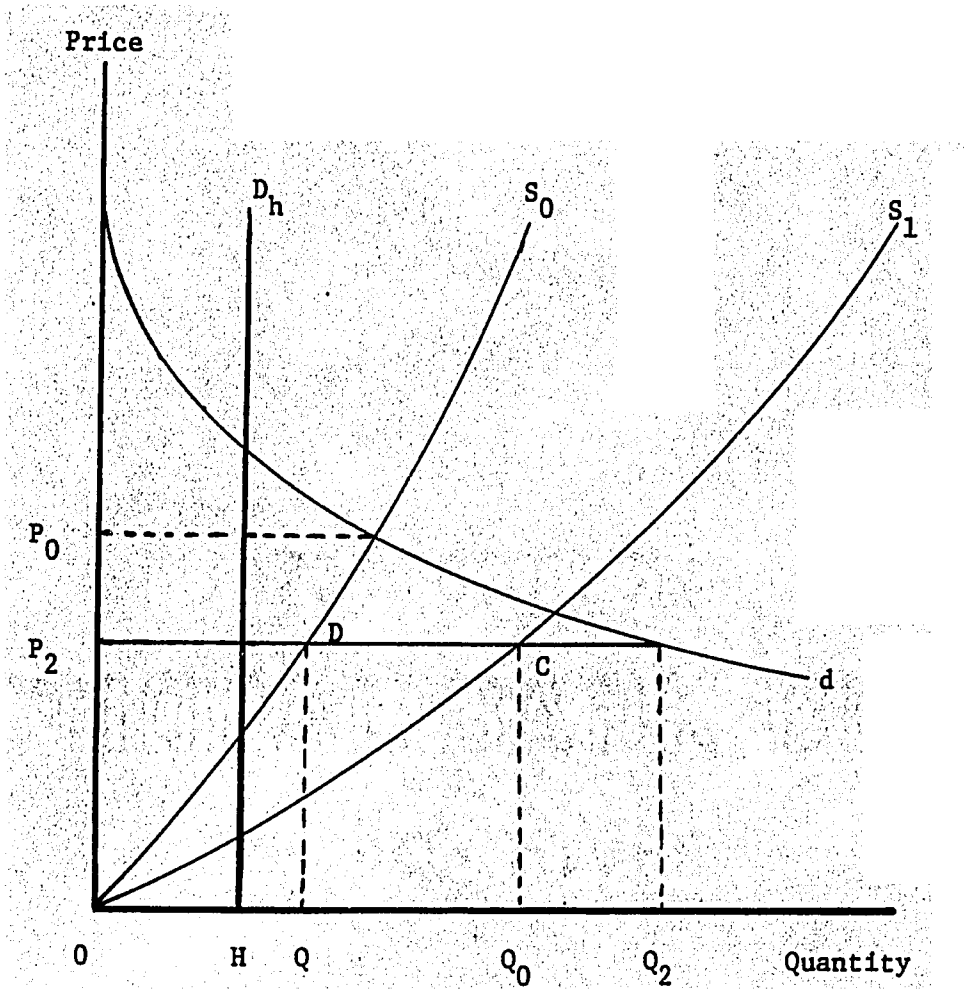

Figure 3.2 Model of Benefits from Wheat Varietal Improvement

have been government intervention in the absence of HYV adoption. The question is what would have been the government's policy and where would price P_2 have been located in Figure 3.2? For this analysis, the assumption is be made that the government's policy would have been to import the deficit and that the pricing policy would have remained the same. That is the wheat price P_2 would have been the same under the two situations.

The assumption that the price would have stayed at the same level is based on the following. Wheat is the staple food of Pakistan. Seventy-two percent of all calories and 76 percent of all protein consumption is derived from cereals in Pakistan of which wheat makes up 90 percent of all cereal intake (Khan et al, 1976). Pakistani governments have always been sensitive to the wheat price and the social unrest that can be caused by high wheat prices. When asked who has the final say in the cabinet on the level that wheat prices are to be set, the reply is the Minister of the Interior who is responsible for law and order.[6/]

Under the assumption that the Government would have intervened and kept the price at P_2 in the absence of the adoption of HYV's, the change in PS would then be Area DOC. This area corresponds to that amount saved because of lower costs per unit of output and represents

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6/ What is required is a model of Government behavior that would predict their policies under various 'what-if' scenarios. The state of the art in this area is somewhat limited. For an attempt to introduce government behavioral equations into models, see Gerrard (1981).

a gain. Because the price stays the same the loss in revenue to producers from a price decrease as described by Figure 3.1 is zero. This also means that the change in CS is zero since there was no change in the price. Thus GARB is equal to ΔPS which is equal to Area DOC.[7/]

As noted previously, imports are Q_0Q_2 given supply curve S_1. In the absence of HYV's (i.e. supply curve S_0), an additional amount QQ_0 would have been imported at a cost in foreign exchange of QQ_0 x P_w (world wheat price). Thus an amount QQ_0 x P_w minus the foreign exchange requirements for the development of HYV's represents a gain to Pakistan in that these funds may then be spent on other goods and services.

Table 3.1 presents the prices, quantities and shift parameters used to calculate GARB. The price (P_2) is the procurement price and the quantity (Q_0) is yearly production.

The yearly supply parameter k_t is derived in Appendix C and is based on a HYV wheat yield advantage of 1.40 weighted by the proportion of area sown to HYV wheat in Pakistan [8/] (table C-5). As stated in the objectives in Chapter 1, the analysis was to only look at benefits derived from research and extension that the Pakistan agri-

7/ The home consumption demand curve D_hH in Figure 3.2 does not enter into the calculations. The gain by producers from a lower cost per unit of output as expressed by Area DOC exists regardless of the market the wheat ends up in.

8/ The yield advantage figure of 1.40 is derived from On-Farm Yield Constraints data and is the average increased yield (i.e. 40%) from using an HYV variety over an old tall variety holding other inputs constant. See Appendix C for the construction of the yield advantage figure.

Table 3.1 Wheat Prices, Production and Supply Shift Parameters, Pakistan

Year	Procurement 1/ Wheat Price (P_2) (1)	Wheat 1/ Production (Q_0) (2)	Wheat Shift Parameter k 2/ Category III (k_2) (3)	Category IV (k_1) (4)	Total (5)
	(Rs./tonne)	(000's tonnes)	(Percent)		
1964-65	361.8	4,591	2.8	-	2.8
1965-66	361.8	3,916	7.7	-	7.7
1966-67	375.3	4,335	12.1	-	12.1
1967-68	455.5	6,418	13.8	-	13.8
1968-69	402.0	6,618	16.4	-	16.4
1969-70	455.5	7,294	17.2	-	17.2
1970-71	455.5	6,476	17.5	-	17.5
1971-72	455.5	6,890	18.3	-	18.3
1972-73	602.8	7,442	18.5	-	18.5
1973-74	683.3	7,629	18.6	-	18.6
1974-75	991.3	7,674	19.8	0.6	20.4
1975-76	991.3	8,691	18.4	2.5	20.9
1976-77	991.3	9,144	18.7	3.7	22.4
1977-78	991.3	8,367	18.2	4.6	22.8
1978-79	1,205.8	9,950	14.1	9.2	23.3
1979-80	1,250.0	10,851	10.6	13.9	24.5
1980-81	1,450.0	11,473	6.8	18.2	25.0

Sources: 1/ Agricultural Statistics of Pakistan, GOP, 1981.
2/ Table C-5 and text of Appendix C.

cultural research and extension system played a part. Thus table 3.1 presents two shifters; k_1 being the yield advantage figure 1.40 weighted by the proportion of hectares sown to all HYV wheat varieties and k_2 being 1.40 weighted by the proportion of hectares sown to HYV wheat varieties that are both CIMMYT/Pakistan contributions. As noted the shift parameter k_2 falls off sharply because of the increase in use of HYV varieties (Introductions) that Pakistan did not contribute to.

The benefits from the adoption of HYV wheat varieties are calculated as described by Figure 3.2.[9/] The model utilized a supply elasticity of 0.30 and a demand elasticity of -0.10 as discussed in Appendix D.

Table 3.2 presents the benefits and foreign exchange savings and are both in 1959-60 constant rupees having been deflated by an agricultural deflator (D2).[10/] The benefits calculated using shifter k_2 tapers off in the latter years reflecting the increased use of HYV introductions. This is also true for the foreign exchange savings

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9/ The ΔPS which is Area DOC in figure 3.2 is calculated using the same formula as calculating Area AOC in Figure 3.1. The Foreign exchange earnings are calculated by using the approximation formula by Akino and Hayami (1974). $QQ_0 \times P_w = (1 + \gamma)kP_wQ_0$. ($P_w$ can be found in table E-1, Appendix E.)

10/ The choice of the agricultural wages deflator (D2) over the Pakistan CPI deflator results in lower yearly 1959-60 constant benefits (see table B-6, Appendix B). The choice of D2 as the deflator of the benefits is compatible with its use to deflate research salary expenditures that are used to calculate rates of return in section 3.5.1.

Table 3.2 Benefits and Foreign Exchange Savings from HYV Wheat Adoption

Year	Benefits (GARB) Category III (1)	Benefits (GARB) Category IV (2)	Benefits (GARB) Total (3)	Foreign Exchange Savings Category III (4)	Foreign Exchange Savings Category IV (5)	Foreign Exchange Savings Total (6)
	(mil's 1959-60 Rs)					
1964-65	31.6	-	31.6	3.1	-	3.1
1965-66	67.8	-	67.8	7.3	-	7.3
1966-67	111.9	-	111.9	11.5	-	11.5
1967-68	211.7	-	211.7	16.7	-	16.7
1968-69	211.4	-	211.4	14.2	-	14.2
1969-70	255.4	-	255.4	16.4	-	16.4
1970-71	213.0	-	213.0	15.6	-	15.6
1971-72	218.6	-	218.6	16.1	-	16.1
1972-73	291.7	-	291.7	41.7	-	41.7
1973-74	195.5	-	195.5	41.9	-	41.9
1974-75	263.1	8.0	271.1	81.6	2.5	84.1
1975-76	244.2	33.1	277.3	55.0	7.4	62.4
1976-77	255.6	50.6	306.2	48.0	9.5	57.5
1977-78	192.8	48.7	241.5	38.1	9.6	47.7
1978-79	200.2	130.6	330.8	41.0	26.7	67.7
1979-80	157.8	206.9	364.7	32.7	42.8	75.5
1980-81	115.0	307.7	422.7	27.0	72.4	99.4

Source: See text.

that are calculated using k_2. The foreign exchange savings presented in table 3.2 are not corrected for foreign exchange used in the development of HYV's however, given that P_w are border prices, base Karachi, the cost in handling and transportation of quantity QQ_0 to centers of consumption within Pakistan would equal the correction.

An analysis of the sensitivity of GARB and the foreign exchange savings to a change in the shift parameter was undertaken. A shift of k $\pm$ 15% shifted both GARB and foreign exchange savings by 10 to 15 percent.

3.4 Estimates of the Benefits from Maize Research and Extension

The maize industry in Pakistan is not subject to as much government intervention as the wheat industry. Although maize imports and exports are controlled by the government and virtually no international trade takes place, there is no effective procurement program. Thus, the maize market can be characterized by Figure 3.1 in that price and quantity find their own level. However, a home consumption demand curve is added. It is estimated that between 75 to 80 percent of total maize production in Pakistan is used for home consumption (Chatha and Rehman (1981) and Izuno (1976)). Maize accounts for 5.7 percent of total cereal production. Its per capita consumption is 9 kg per year making it the third most important food crop in Pakistan after wheat and rice (Chatha and Rehman, 1981). The remaining 20 to 25 percent that finds its way on the market is used mainly for the manufacture of starch and animal feed.

The provinces of the Punjab and N.W.F.P. produce almost all the maize grown in Pakistan. The N.W.F.P. produces slightly more maize than the Punjab; 51 to 53 percent of total (Agr. Statistics of Pakistan, 1981). In this analysis, benefits will be calculated for three regions; 1) all Pakistan (Punjab and N.W.F.P.), 2) Punjab and 3) N.W.F.P.[11/]

Figure 3.3 presents the model used in determining the benefits from the adoption of HYV maize varieties. The current situation is depicted by supply curve S_1 and demand curve d intersecting at equilibrium price P_1 and quantity Q_1. Given home consumption demand curve D_hH, quantity OH is consumed at home and quantity HQ_1 would then be marketable surplus. Quantity OQ_1 is then total annual production which equals annual available supply as little is stored and imports and exports are at zero levels.

In the absence of the adoption of HYV maize varieties by producers, S_0 becomes the relavent supply curve. With no government intervention, price P_0 and quantity Q_0 would reign. The stage is now set to calculate ΔCS, ΔPS and GARB. The ΔCS from the shift in the supply curve from S_0 to S_1 is Area ACGB and represents a gain since they can now purchase an increased quantity Q_0Q_1 at price P_1. The cash revenue situation of producers changes from area $ACHQ_0$ to area $BGHQ_1$. The cost of production changes from area AOQ_0 to area BOQ_1. The net

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11/ A split in the benefits between the Punjab and N.W.F.P. is possible because there is little spillover effect. Each Province basically does its own research and the varieties are fairly location specific such that each province has its own varieties.

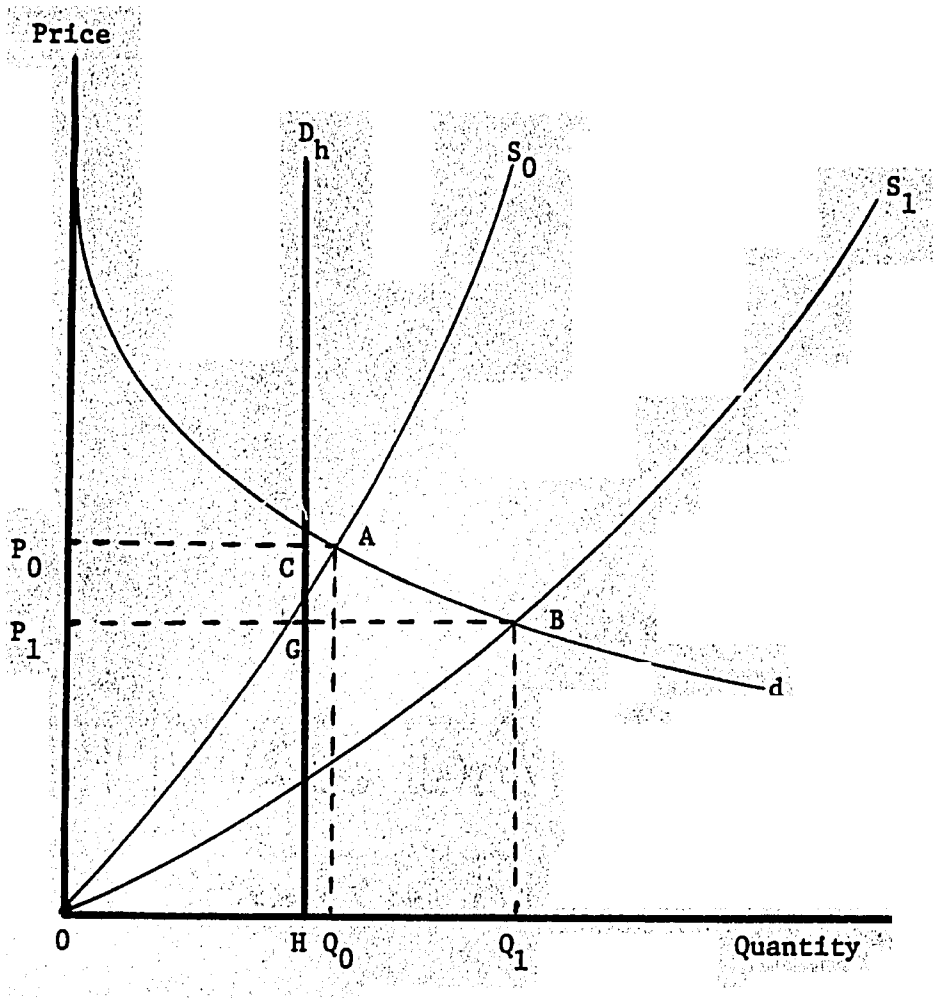

Figure 3.3 Model of Benefits from Maize Crop Varietal Improvement

producer income position (i.e. revenues minus production cost) from the shift in the supply curve from S_0 to S_1 may be positive or negative depending on the supply and demand elasticities.

Hayami and Herdt (1977) have developed approximation formulas to calculate the above areas as follows:12/

Consumer gain

(1) Area ACGB $\approx p_0 q_0 - (kr/\gamma + \eta)$

where r = the marketable surplus ratio HQ_0/OQ_0

Change in Producer's cash revenue

(2) Area $BGHQ_1$ - Area $ACHQ_0 \approx p_0 q_0 k((\eta - r)/(\gamma + \eta))$

Change in production cost

(3) Area BOQ_1 - Area $AOQ_0 \approx p_0 q_o \cdot \frac{k\gamma(\eta - 1)}{(1 + \gamma)(\gamma + \eta)}$

Producers income change

(4) (3) + (2) $= p_0 q_0 \cdot \frac{\gamma}{1 + \gamma}\left(k - k \cdot \frac{1 + \gamma}{\gamma + \eta}\right)$

and

$$p_1 \approx p_0 \left(1 - \frac{k}{\gamma + \eta}\right)$$

$$q_1 \approx q_0 \left(1 + \frac{\eta k}{\gamma + \eta}\right)$$

12/ In their forthcoming book, Hayami and Ruttan (1984, Chapter 11) use formula (1) and (4) above in calculating consumers and producers surplus respectively. However they split producers surplus into the change in producers' consumer surplus (ΔCSP) and a change in producers surplus (ΔPS). Thus the net welfare gain to producers (ΔNGP) is equal to ΔCSP + ΔPS where ΔCSP = area CP_oP_1G and ΔPS = $AP_o0 - BP_10$ from a rightward shift in supply curve S_o to S_1 in Figure 3.3. While this represents a different way of looking at the changes that effect produces, the use of the Hayami-Ruttan formulas provide the same end numbers as does the Hayami-Herdt formulas used in this analysis.

where $p_1 = OP_1$, $p_0 = OP_0$, $q_1 = OQ_1$, $q_0 = OQ_0$.

Table 3.3 presents the prices, quantities and shift parameters for all three regions. The yearly maize shift parameter k_t for all three regions are derived in Appendix C. They are based on maize HYV yield advantage figures calculated from On-Farm Yield Constraints Data weighted by the proportion of area sown to maize HYV's within each region.13/

A yield advantage figure of 1.16 was used for the N.W.F.P. and a figure of 1.24 for the Punjab. Although the data indicated a 1.24 yield advantage for the Punjab (table C-4), the lower figure of 1.16 is also used as a comparison. The yield advantage figure for the all Pakistan region compares the 1.16 figure with a weighted 1.16 + 1.24 (by HYV area sown) figure. Since all varieties are CIMMYT/Pakistan varieties, there are no introduction varieties and a shifter k to represent them as in the case of wheat.

Table 3.4 presents the calculation of benefits for all Pakistan. The benefits are in 1959-60 constant rupees having been deflated by an agricultural wages deflator (D_2).14/ The supply and demand elasticities used follow from the discussion in Appendix D. A supply elasti-

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13/ To be consistent with the formulas by Hayami and Herdt (1977) k is specified as a rightward shift in the pre-innovation supply curve S_0 (i.e. $S_1 = b(1 + k)p^{\gamma}$ in Hayami and Herdt but $S_0 = b(1 - k)p^{\gamma}$ in Akino and Hayami (1978) as described in section 3.2 because the formulas are derived with a leftward shift in the supply curve.)

14/ See Appendix B for a discussion on the deflator and for its source. Also see footnote 10 in section 3.3.

Table 3.3 Maize Prices, Production and Supply Shift Parameters

Year	Maize[1/] Price	Production[1/] Punjab	Production[1/] NWFP	Production[1/] Total	Maize Shift Parameter k[2/] Punjab YA=1.16	Punjab YA=1.24	NWFP YA=1.16	Pakistan YA=1.16	Pakistan YA=weighted 1.16 + 1.24
	(Rs/tonne)	- - - (000 tonnes) - - -			- - - - - - - - - - - - (Percent) - - - - - - - - - - - -				
1967-68	623.0	299	382	681	0.8	1.2	0.8	0.8	1.0
1968-69	475.3	310	303	613	1.1	1.7	1.0	1.0	1.4
1969-70	467.0	323	327	650	1.4	2.2	1.0	1.2	1.6
1970-71	485.8	343	358	701	1.8	2.6	1.1	1.4	1.9
1971-72	590.0	341	349	690	2.2	3.4	1.4	1.8	2.4
1972-73	648.8	329	363	692	2.7	4.8	1.6	2.1	3.2
1973-74	695.3	345	407	752	3.2	4.8	2.1	2.6	3.4
1974-75	1,321.8	326	408	734	4.0	6.0	2.4	3.1	4.2
1975-76	1,208.0	386	402	788	4.8	7.2	3.0	3.9	5.1
1976-77	1,185.3	362	386	748	5.6	8.4	3.4	4.4	5.9
1977-78	1,331.5	392	415	807	6.6	9.8	4.2	5.3	7.0
1978-79	1,635.0	385	399	784	7.4	11.0	4.6	6.0	7.8
1979-80	1,552.0	421	438	859	8.5	12.7	5.6	6.9	9.2
1980-81	1,556.8	445	486	931	9.6	14.4	6.4	7.9	10.4

Sources: 1/ Agricultural Statistics of Pakistan, GOP, 1981.
2/ Table C-11 and text of Appendix C.

Table 3.4 Maize Benefits Under Various Elasticity and k Scenarios: Pakistan Total

Year	I ES=0.08 ED=-0.10 k = -	II ES=0.15 ED=-0.10 k=+15%	III ES=0.15 ED=-0.10 k = -	IV ES=0.15 ED=-0.10 k=-15%	V ES=0.15 ED=-0.20 k = -	VI ES=0.30 ED=-0.20 k = -
	(1)	(2)	(3)	(4)	(5)	(6)
	(mil's 1959-60 Rs.)					
1967-68	1.7	1.8	1.5	1.4	1.5	1.3
1968-69	1.4	1.5	1.3	1.1	1.2	1.1
1969-70	1.6	1.7	1.5	1.3	1.5	1.3
1970-71	2.0	2.1	1.9	1.5	1.9	1.6
1971-72	2.9	3.0	2.6	2.2	2.6	2.2
1972-73	3.5	3.7	3.1	2.6	3.0	2.7
1973-74	3.0	3.1	2.7	2.2	2.6	2.2
1974-75	5.9	6.1	5.2	4.3	4.9	4.3
1975-76	6.7	6.9	5.9	4.9	5.5	4.8
1976-77	7.2	7.3	6.1	5.1	5.8	4.9
1977-78	9.4	9.6	8.0	6.5	7.4	6.2
1978-79	12.6	12.5	10.3	8.2	9.5	7.9
1979-80	15.1	14.7	12.1	9.9	10.9	9.0
1980-81	19.1	18.2	14.8	11.7	13.1	10.6

Note: The marketable surplus ratio (r) is 0.25 for all scenarios and the yield advantage (YA) is 1.16.

city of 0.15 and a demand elasticity of -0.10 are used. A sensitivity analysis is done changing the supply and demand elasticities as well as the supply shifter k; (k ± 15%). The benefits increase yearly as expected in all six scenarios reflecting the increased hectares sown to maize HYV's.

Table 3.5 presents the calculations of benefits for the Punjab and N.W.F.P. Provinces. A supply elasticity of 0.075 was used in each region along with a demand elasticity of -0.10 (see Appendix D). Although not presented, a sensitivity analysis was done in the same manner as that presented in Table 3.4 with similar percentage change results.

3.5 The Rate of Return to Wheat and Maize Research and Extension

The rate of return to investments in wheat and maize crop development research and extension can be calculated using the estimated benefits from sections 3.3 and 3.4 of this chapter and the associated expenditures developed in Appendix A. Previous studies have calculated both an internal and an external rate of return which are overall average rates of return and some studies have estimated a marginal internal rate of return.

The internal rate of return is that rate r_i which makes the sum of discounted net returns exactly equal to zero as shown in 3.5:

$$\sum_{t=0}^{T} \frac{R_t - C_t}{(1 + r_i)^t} = 0 \qquad (3.5)$$

where R_t is the return (GARB) in each year t and C_t the cost in each

Table 3.5 Maize Benefits; Punjab and NWFP Provinces

Year	Punjab		NWFP	Pakistan Total	
	YA=1.16 (1)	YA=1.24 (2)	YA=1.16 (3)	YA=1.16 1/ (4)	YA=weighted 1.16 + 1.24 (5)
	(mil's 1959-60 Rs.)				
1967-68	0.8	1.2	0.8	1.6	2.0
1968-69	0.7	1.0	0.6	1.3	1.6
1969-70	0.9	1.3	0.6	1.5	1.9
1970-71	1.1	1.6	0.7	1.8	2.3
1971-72	1.5	2.3	1.0	2.6	3.3
1972-73	1.8	2.7	1.3	3.1	4.0
1973-74	1.5	2.3	1.2	2.7	3.5
1974-75	3.0	4.5	2.2	5.2	6.7
1975-76	3.5	5.3	2.4	5.9	7.7
1976-77	3.7	5.4	2.5	6.2	7.9
1977-78	4.6	6.9	3.4	8.4	10.3
1978-79	6.2	9.4	4.2	10.4	13.6
1979-80	7.1	10.6	5.0	12.1	15.6
1980-81	8.6	12.7	6.1	14.7	18.8

1/ Totals may not equal totals in Table 3.4, column (3) because of rounding.

year t (research and extension expenditures) and T is the year in which research and extension ceases to produce returns. The internal rate of return (r_i) can be interpreted to mean that on average, each rupee (in our case) invested in research and extension returned r_i percent annually from the date of the initial investment.

The external rate (r_e) is calculated using the following formula: (see Peterson 1971)

$$r_e = \frac{100\ (iP + F)}{C} \qquad (3.6)$$

where i is the external rate of interest (opportunity cost), P is the accumulated past returns (GARB), F is the annual flow of future returns and C the accumulated past costs (research and extension expenditures). The external rate of return r_e evaluates the sum of past returns expressed as a flow plus the flow of future returns relative to the cost. The external rate of return can be interpreted to mean that from the date of the initial investment, the average rupee invested returned i percent annually and is now paying off at a rate of r_e percent per year into perpetuity.[15/]

The calculation of a marginal internal rate of return from the benefits and costs from the index number approach has been suggested

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15/ The external rate of return is closely related to the benefit-cost ratio (Allen, 1975, p. 730; and Peterson, 1971, p. 148). The benefit-cost ratio (B/C) is arrived at using the same data as formula 3.6 as follows;

$$B/C = \frac{P + F/i}{C} = \frac{(iP + F)}{iC}$$

by Peterson (1971). Since a marginal rate of return conveys information on the returns from additional investments, it has more meaning in a decision making context and also is more comparable to the marginal rates derived from a production function approach (Chapter 4).

An approximation of a marginal rate of return is made by first finding the increment in yearly returns over some base period. For example, given t-10 is the base year, increments for each of the nine years t to t-9 are calculated as (t-i) - (t-10) where i = 1 to 9. Secondly, assuming an appropriate lag in expenditures (i.e. t-7) so as to match the time period between expenditures and the returns resulting from the expenditures, the internal rate of return formula in (3.5) is used to calculate r_i.

3.5.1 The Rate of Return to Wheat

Table 3.6 presents the external, internal average and marginal rates of return to investments in wheat research and extension. The benefits (GARB) outlined in table 3.2 column (1) and the expenditures constructed in table A-3, Appendix A are used to calculate the rates of return.16/ As indicated in Chapter 2, conventional extension was thought not to play a major role in the overall research and extension contribution to increased productivity. Thus two research expenditure figures are used in the calculations of the rates of return. The

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16/ The foreign exchange savings estimated in section 3.3 are not included as benefits. As stated by Akino and Hayami (1974, p.7) "it is difficult to estimate the gain in national economic welfare due to the saving of foreign exchange in a term which is comparable with consumers' or producers' surplus."

Table 3.6 Estimated Rates of Return to Wheat R&E; Pakistan

	Research and Extension Expenditure Scenarios					
	Including Conventional Extension			Excluding Conventional Extension		
	k + 15% (1)	k (2)	k - 15% (3)	k + 15% (4)	k (5)	k - 15% (6)
External Rate						
1) Cumulated Past Returns	3714	3232	2746	3714	3232	2746
2) Past Returns as Annual Flow	371.4	323.2	274.6	317.4	323.2	274.6
3) Annual Future Returns	100.0	100.0	100.0	100.0	100.0	100.0
4) Total 2) + 3)	471.4	423.2	374.6	471.4	423.2	374.6
5) Past R&E Expenditures	158.9	158.9	158.9	82.6	82.6	82.6
6) Rate of Return (100 x 4)/5))	296.7	266.3	235.7	570.7	512.3	453.5
Internal Rate	62	58	55	71	68	65
Marginal Rate	67	64	60	85	81	77

Note: The benefits used in arriving at the rates of return are those found in column (1) of Table 3.2. An external rate of interest of 10% is used in the calculation of the external rate of return.

first is research and extension expenditures including conventional extension and the second is research and extension expenditures excluding conventional extension expenditures.

The rates of return as presented in Table 3.6 are substantial but in line with previous studies in other countries (Ruttan, 1982, p. 242). The external rate of return was calculated using an external rate of interest of 10 percent which may be low. Increasing i to 15 percent results in a return of 368.0 and 707.9 percent in comparison to the rates in columns (2) and (5). Annual future returns are taken to be roughly two-thirds of the average returns in the last three years. The external rate of return of 266.3 percent implies that the average rupee spent on R & E returned 10 percent annually from the start of the initial investment and is now paying off at the rate of 266.3 percent annually into perpetuity. In the benefit/cost mode, using a 10 percent external interest rate, a one rupee investment returned 26.6 rupees over the period.

The internal rates of return were calculated by assuming future returns and expenditures were equal to the average of the last three years.[17/] The 1960-61 expenditure figure was used to extend expenditures back to 1957-58 so as to leave a seven year lag between the time of the initial expenditure and the resulting benefits in 1964-65. Since both the returns and expenditures were deflated, the returns are in terms of real rates of return. The internal rate of return of 58

17/ Little difference in the magnitudes of the rates of return exists if both returns and costs are not carried forward but truncated.

percent means that on average, each rupee invested in R & E returned 58 percent (or 0.58 Rs.) annually from the date of the initial investment.

The marginal rates of return were obtained as previously described. The average of the years 1964-65 to 1966-67 were used as the base year and the average of the last three years used as future returns. A 64 percent marginal internal rate of return implies that the last rupee invested in R & E resulted in a 64 percent (or 0.64 Rs) return now and into perpetuity.

As discussed in the summary (section 3.7) the rates of return treat support from international agencies as a free good. If Pakistan had to purchase the services of International agencies, the rates of return would be substantially lower. Appendix A, table A-5 presents CIMMYT and Pakistan combined expenditures. The CIMMYT expenditures on wheat represent the funds that Pakistan would have had to spend to operate a CIMMYT type operation incountry. Internal rates of return using the CIMMYT/Pakistan expenditures from table A-5, Appendix A columns (5) and (6) and total returns from table 3.2 were calculated. Internal rates of return of 28 and 30 percent were obtained.

3.5.2 The Rate of Return to Maize

Table 3.7 presents the external and internal rate of return to investments in maize research and extension. The benefits presented in table 3.4 and 3.5 and the expenditures constructed in Appendix A, tables A-3 and A-4 are used to calculate the rates of returns. As in

Table 3-7 Estimated Rates of Return to Maize R&E: Pakistan

	Pakistan				Punjab		NWFP
	YA=1.16			YA=weighted 1.16 + 1.24	YA=1.16	YA=1.24	YA=1.16
	k + 15% (1)	k (2)	k - 15% (3)	(4)	(5)	(6)	(7)
External Rate							
1) Cumulated Past Returns	92.2	77.0	62.9	94.4	45.0	64.4	32.0
2) Past Returns as Annual Flow	9.2	7.7	6.3	9.4	4.5	6.4	3.2
3) Annual Future Returns	11.4	9.3	7.5	10.5	5.5	8.2	3.8
4) Total 2) + 3)	20.6	17.0	13.8	19.9	10.0	14.6	7.0
5) Past R&E Expenditures 1/							
5.1) E1	34.9	34.9	34.9	34.9	20.1	20.1	15.9
5.2) E2	26.8	26.8	26.8	26.8	15.3	15.3	11.3
6) Rate of Return							
6.1) E1 (100x4)/5.1))	58.9	48.7	39.6	57.1	49.6	72.6	44.2
6.2) E2 (100x4)/5.2))	78.8	63.4	51.5	74.4	65.2	95.2	62.2
Internal Rate							
E1	21	19	17	23	18	24	19
E2	24	23	21	25	22	27	24

Note: An external rate of interest of 10% is used in the calculation of the external rate of return.

1/ E1 = R&E including conventional extension expenditures.
E2 = R&E excluding conventional extension expenditures.

the wheat analysis, two expenditure streams are used, the first including and the second excluding conventional extension expenditures.

The rates of return presented in table 3.7 are those of the all Pakistan, Punjab and N.W.F.P. regions. The benefit streams (GARB) used in the analysis specifically come from table 3.4, columns (2), (3) and (4) and table 3.5 columns (4), (1), (2) and (3) in that order

The external rate of return was calculated using an external interest rate of 10 percent. Increasing i to 15 percent results in a return of 59.7, 60.8 and 54.2 percent in comparison with the rates in columns (2), (5) and (6) for expenditures E_1. Annual future returns are taken to be 75 percent of the last three years. The external rates of return of 48.7 percent implies that the average rupee spent on R & E (E_1) returned 10 percent annually from the initial investment and is now paying off at the rate of 48.7 percent annually into perpetuity. The benefit-cost ratio using a 10 percent external rate of interest is 4.87/1 meaning that a one rupee investment returned 4.87 rupees over the period.

The internal rates of return were calculated by assuming future returns and expenditures were equal to the average of the last three years of benefits and expenditures. A seven year lag exists between expenditures which began in 1960-61 and the benefits which began in 1967-68. The internal rate of return (real) of 19 percent means that on average, each rupee invested in R & E returned 19 percent (or 0.19 Rs.) annually from the date of the initial investment.

Marginal rates of return were also calculated (not presented) with the results slightly higher than but in most cases identical to the inter nal rates or teturn due to founding. In the marginal rates of return analysis, the average of the years 1967-78 to 1969-70 were used as the base year and the average of the last three years used as future returns.

3.6 The Distribution of Benefits

The total returns (GARB) can be disaggregated to find the changes in the income distributions among various groups from the adoption of HYV's. The first and most convenient categories to disaggregate GARB is into the consumer and producer components. The specification of the wheat model in Section 3.3 indicated that the gains were made by producers as a group and that the change in consumers welfare was zero. However, both consumer and produces may have gained from the foreign exchange savings.

The specification of the maize model does allow for changes in consumer surplus and producer income from the adoption of HYV maize. Tables 3.8 through 3.11 present the changes in consumer surplus, changes in producer revenues and the changes in production costs that are derived from the formulas discussed in Section 3.4. The benefits in Table 3.8 and 3.9 are derived with an elasticity of supply and demand of 0.15 and -0.10 respectively and under two marketable surplus ratios (r). In scenario I (r = .25), consumers gain, producers lose on the revenue side but gain because of a decrease in production

Table 3.8 Distributional Effects of HYV Maize Adoption; Scenario I

Year	Consumers Surplus (CS) (1)	Change in Producer Revenue (R) (2)	Change in Production Costs (PC) (3)	Producers Overall Surplus (2)-(3) (4)	GARB (1)+(4) (5)
	(mil's 1959-60 Rs.)				
1967-68	1.8	-1.1	-0.8	-0.3	1.5
1968-69	1.5	-0.9	-0.7	-0.2	1.3
1969-70	1.7	-1.0	-0.8	-0.2	1.5
1970-71	2.1	-1.2	-1.0	-0.2	1.9
1971-72	3.0	-1.8	-1.4	-0.4	2.6
1972-73	3.6	-2.2	-1.7	-0.5	3.1
1973-74	3.1	-1.8	-1.4	-0.4	2.7
1974-75	6.1	-3.6	-2.8	-0.8	5.3
1975-76	6.8	-4.1	-3.2	-0.9	5.9
1976-77	7.1	-4.3	-3.3	-1.0	6.1
1977-78	9.2	-5.5	-4.3	-1.2	8.0
1978-79	11.9	-7.2	-5.6	-1.6	10.3
1979-80	13.9	-8.3	-6.5	-1.8	12.1
1980-81	17.0	-10.2	-8.0	-2.2	14.8

Note: ES = 0.15, ED = -0.1, r = 0.25.

Table 3.9 Distributional Effects of HYV Maize Adoption; Scenario II

Year	Consumer Surplus (CS) (1)	Change in Producer Revenue (R) (2)	Change in Production Costs (PC) (3)	Producers Overall Surplus (2)-(3) (4)	GARB (1)+(4) (5)
	(mil's 1959-60 Rs.)				
1967-68	1.1	-0.4	-0.9	0.5	1.6
1968-69	0.9	-0.3	-0.7	0.4	1.3
1969-70	1.0	-0.3	-0.8	0.5	1.5
1970-71	1.2	-0.4	-1.0	0.6	1.8
1971-72	1.8	-0.6	-1.4	0.8	2.6
1972-73	2.2	-0.7	-1.7	1.0	3.2
1973-74	1.8	-0.6	-1.4	0.8	2.6
1974-75	3.6	-1.2	-2.8	1.6	5.2
1975-76	4.1	-1.4	-3.2	1.8	5.9
1976-77	4.3	-1.4	-3.3	1.9	6.2
1977-78	5.5	-1.8	-4.3	2.5	8.0
1978-79	7.2	-2.4	-5.6	3.2	10.4
1979-80	8.3	-2.8	-6.5	3.7	12.0
1980-81	10.1	-3.4	-8.0	4.6	14.7

Note: ES = 0.15, ED = -0.1, r = 0.15.

Table 3.10 Distributional Effects of HYV Maize Adoption; Scenario III

Year	Consumers Surplus (CS) (1)	Change in Producer Revenue (R) (2)	Change in Production Costs (PC) (3)	Producers Overall Surplus (2)-(3) (4)	GARB (1)+(4) (5)
	(mil's 1959-60 Rs.)				
1967-68	1.3	-0.3	-0.5	0.2	1.5
1968-69	1.0	-0.2	-0.4	0.2	1.2
1969-70	1.2	-0.2	-0.5	0.3	1.5
1970-71	1.6	-0.3	-0.6	0.3	1.9
1971-72	2.1	-0.4	-0.9	0.5	2.6
1972-73	2.5	-0.5	-1.0	0.5	3.0
1973-74	2.1	-0.4	-0.9	0.5	2.6
1974-75	4.0	-0.8	-1.7	0.9	4.9
1975-76	4.5	-0.9	-1.9	1.0	5.5
1976-77	4.8	-1.0	-2.0	1.0	5.8
1977-78	6.1	-1.2	-2.5	1.3	7.4
1978-79	7.8	-1.6	-3.3	1.7	9.5
1979-80	9.0	-1.8	-3.7	1.9	10.9
1980-81	10.7	-2.1	-4.5	2.4	13.1

Note: ES = 0.15, ED = -.2, r = 0.25.

Table 3.11 Distributional Effects of HYV Maize Adoption; Scenario IV

Year	Consumers Surplus (CS) (1)	Change in Producer Revenue (R) (2)	Change in Production Costs (PC) (3)	Producers Overall Surplus (2)-(3) (4)	GARB (1)+(4) (5)
	(mil's 1959-60 Rs.)				
1967-68	0.8	0.3	-0.5	0.8	1.6
1968-69	0.6	0.2	-0.4	0.6	1.2
1969-70	0.7	0.2	-0.5	0.7	1.4
1970-71	0.9	0.3	-0.6	0.9	1.8
1971-72	1.2	0.4	-0.9	1.3	2.5
1972-73	1.5	0.5	-1.0	1.5	3.0
1973-74	1.3	0.4	-0.9	1.3	2.6
1974-75	2.4	0.8	-1.7	2.5	4.9
1975-76	2.7	0.9	-1.9	2.8	5.5
1976-77	2.8	0.9	-2.0	2.9	5.7
1977-78	3.6	1.2	-2.5	3.7	7.3
1978-79	4.5	1.6	-3.3	4.9	9.4
1979-80	5.2	1.8	-3.7	5.5	10.7
1980-81	6.4	2.1	-4.5	6.6	13.0

Note: ES = 0.15, ED = -0.2, r = 0.15.

costs. Overall however, as a group, the change in producer income is negative.[18/] However, if r = .15 as in scenario II (Table 3.9), meaning that marketable surplus is now only 15 percent of total production, the distribution between consumers surplus and consumers revenue changes leaving producers income as a group positive but GARB unchanged. When r = .35 (not presented), consumers gain more and producers revenues and total income decrease relative to scenario I.

Tables 3.10 and 3.11 present results similar to tables 3.8 and 3.9 but with the demand elasticity changed from -0.10 to -0.20. Scenario III (Table 3.10) indicates that changing the demand elasticity to -0.20 has an effect similar to changing r to .15 in scenario II. From other analysis (not presented), a supply elasticity of 0.08 results in a negative overall producer income figure and an elasticity of 0.30 results in a positive overall producer income.

The above analysis indicates that the correct specification of the supply and demand elasticities and marketable surplus ratio are more important when disaggregating GARB than in the estimation of GARB itself. While GARB remains relatively insensative to changes in elasticities and the changes in marketable surplus ratio, benefits to various groups are very sensitive. For example, the difference between scanario I and scenario III from just changing the demand elasti-

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18/ For the adopters of HYV maize, there would also exist a distribution of gains and losses, i.e., earlier adoptors gaining more than latter adoptors. For those not adopting HYV maize, there is a direct loss in revenue which is transferred to consumers (see Scobie and Posada, 1977, p. 42).

city from -0.10 to -0.20 decreases consumer surplus by 35-40 percent, changes the overall producers income position from a negative to a positive while only decreasing GARB by about 10 percent.19/

The change in consumer surplus and producers overall income can be further disaggregated. Scobie and Posada (1977) disaggregated the change in consumer surplus by income level and producer surplus by farm size on an irrigated and non-irrigated basis. Hayami and Herdt (1977) disaggregate the change in overall producer revenue by small and large producers. To do such analysis properly requires a substantial amount of data as well as data accuracy. The above discussion on disaggregating GARB bears out its sensitivity to the accuracy of the data and various parameters used in the analysis.

The Hayami and Herdt (1977) model of disaggregating producer gains specifies two supply curves, one being a supply curve which is the sum of individual output of small producers and the other the sum of the individual out put of large producers at various prices.20/ Given a demand curve, the supply elasticities, marketable surplus

19/ Hayami and Herdt (1977) develop formulas for a variable home consumption case. That is there is a shift (usually to the right) of the demand curve. $D_h d$ in figure 3.3 from a change in home consumption (Δh) due to a change in output (q). An estimate of the elasticity of home consumption with respect to output $(\frac{\Delta h}{\Delta q} \cdot \frac{q}{h})$ is not available for Pakistani maize.

However, as Hayami and Herdt (1977, p. 254) state "the magnitude of possible effects on consumers' welfare and producers' cash income are sufficiently small so that the basic conclusion on intersectoral income distribution is not effected."

20/ The same model could be used to disaggregate irrigated and non-irrigated producers.

ratios (r) and shift parameters (k) must all be specified separately for small and large producers. The formulas to estimate the changes are found in Hayami and Herdt (1977, p. 248). The available data to estimate the disaggregated changes at this time are inadequate for both the maize and wheat commodities. The fact that many of the parameters required in the formulas would be quesstimates and knowing that the distributional changes are very sensitive to parameter changes, the results would only serve as an illustration which is already supplied by Hayami and Herdt.[21/] The results of such a study could prove interesting because as found by Hayami and Herdt, small producers cash revenue was positive whereas large producers cash revenue was negative. This leads to a positive overall cash income effect for small producers in most scenarios but leaving negative the large producer incomes.

3.7 Summary and Discussion

This chapter was concerned with estimating the rates of return and the distributional consequences from agricultural research and extension investments in Pakistan. Benefits accruing from the investments in wheat and maize research and extension programs were estimated using the index number approach. The analysis followed the lead of Hayami and Herdt with respect to the methodology with the exception

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21/ Another complication existed in carrying out a distributional analysis on an income level or by farm size because at the time of analysis, this information was not available because of the delay in the publication of the 1981 census.

that the model had to be altered to account for government intervention in the case of wheat.

External, internal and marginal rates of return were calculated for each crop. The rates of return to wheat were very high with internal rates of return ranging from 55 to 71 percent depending on the scenario. Although the returns are very high, they are similar to rates of return to wheat research and extension in other countries. Even when the supply shifter k is cut in half, returns still average 30 percent.

The rates of return to investments in maize research and extension are considerably lower than the wheat figures but still high in their own right. Internal rates of return ranged from 17 to 27 percent depending on the scenario. Although maize expenditures are somewhat less than the expenditures on wheat and the yield advantage of maize is half that of wheat, the rate of return to maize would be similar or higher than wheat given wheat's area and area sown to HYV's.

In the wheat analysis, the supply shifter k was constructed so as not to include introductions. This does not negate the fact that the returns to both wheat and maize treat the support from international agencies as a free good. The rates of return figures are therefore to be looked upon by individual contributors to the agricultural research and extension system as the returns that may be expected from a broad based research and extension agenda within each crop. Of interest is that a calculation of the rate of return to wheat research and exten-

sion had Pakistan purchased the total services of CIMMYT resulted in a rate of return of 28 to 30 percent.

Total returns were disaggregated into changes in consumer surplus, producer revenue and production costs. It was noted that while total returns were not very sensitive to changes in parameters like elasticities and marketable surplus ratios, distributions of the total returns were overly sensitive. The combination of the sensitivity to various parameters and inadequate data precluded a thorough analysis of further disaggregating the changes in consumer surplus and producer incomes.

CHAPTER 4

Estimation of the Productivity Model and Overall Returns to Research and Extension

4.1 Introduction

Pakistan's agricultural productivity (crops) has increased substantially starting in 1967-68 which represents the start of the Pakistan Green Revolution period. This is evidenced by the increase in the productivity index shown in Appendix B, Table B-1. The purpose of this chapter is to identify and establish the contribution of the major sources of overall productivity growth in Pakistan's agriculture.

Two main approaches have been used to identify overall sources of productivity growth and establish their contribution. The first is an "inputs saved" approach which in essence is the difference between the value of present day technological inputs in producing today's agricultural output minus the value of yesterday's (years) technological inputs in producing today's agricultural output. Schultz (1953), in a study of United States agriculture for the period 1920-50 concluded that despite the considerable increase in agricultural output over the period, the aggregated value of traditional agricultural inputs remained virtually constant. In a recent study, Brinkman and Prentice (1983) used the inputs saved approach to estimate an internal rate of return to investments in agricultural research and extension. They found that the inputs saved over the period 1956 to 1978 returned an internal rate of return of 65.7 percent to the Province of Ontario, Canada.

The most popular approach has been to use a production function. The level of agricultural output is estimated as a function of the level of traditional and non-conventional inputs. The non-conventional inputs such as education, research and extension are included as separate arguments. A full list of production function type studies are found in Ruttan (1982, pp. 242-246). Good literature reviews on the topic exist in Davis (1979) and Norton and Davis (1980).

Many production function estimates utilize cross-section or pooled cross-section time series data to avoid multicollinearity problems. Other studies such as Lu et al have used a total factor productivity index regressed on the non-conventional inputs to eleviate the multicollinearity problem. This is the approach adopted in this study fr the following reasons. First, although much of the data exists to estimate a time series production function of the Pakistani agricultural sector, severe multicollinearity problem do arise. For example, the study by Naqvi et al (1983) was unable to estimate a very convincing agricultural production function for the P.I.D.E. Macro-Economic Model of Pakistan's economy for this reason. Secondly, the data required to estimate a pooled time series cross-section model using Cencus years and Districts although almost complete is still deficient.

Following Lu et al (1979), the level of productivity (P_t) in year t is a function of the current weather conditions (W_t), the current education level of farmers (ED_t) and the impact of research (RS_t) and

Extension (EX_t) in the current year from previous expenditures on research and extension. Since a main objective is to obtain the contribution and rate of return to expenditures on research that the Pakistan research system is involved in, a variable is added (HYV_t) representing high yielding varieties that are introductions from other countries. The productivity model is specified in equation (4.1).

$$P_t = A\Pi\ RS_t^{\alpha_1} EX_t^{\alpha_2} HYV_t^{\alpha_3} ED_t^{\alpha_4} e^{\alpha_5 W_t} \qquad (4.1)$$

The actual data series used in estimating the parameters of equation (4.1) are found in Appendix B, Tables B-1 and B-3 along with a narative on their construction and the data sources. For several of the variables, two different data series have been constructed and are used in turn in estimating the parameters of equation (4.1). For example, the research variable is constructed two different ways. The first uses a distributed lag method that has been used in previous studies. The second is the construction of a research stock variable which will be compared to the results from the distributed lag approach. Two extension variables have also been constructed and are explained in section 4.2 and Appendix B. Two different variables also exist for the HYV introductions variable and the weather variable and are self explanatory in the specifications of the variables as follows:

P_t = the aggregate multifactor productivity index for crops in Pakistan. Two productivity indexes exist and are used in

the estimations;

1) PI1 = an arithmetic productivity index

2) PI2 = a geometric (Solow) productivity index.

PS_t = the impact of research in the current year. Two variables have been constructed;

1) RS1 = a stock variable of research represented by the summation of the research expenditures of the previous ten years.

2) RS2 = a second degree polynomial distributed lag with lag lengths of 8, 10, and 12 years using research expenditures R as the data

EX_t = the impact of extension in the current year and is a stock variable represented by the sum of extension expenditures of the current and previous 10 years.

1) EX1 = conventional field assistance type extension expenditures plus seed multiplication and distribution costs plus PARC and donor agency extension related activities.

2) EX2 = EX1 excluding conventional field assistance extension.

HYV_t = a variable representing high yielding varieties that were introductions to Pakistan meaning that the Pakistan agricultural research system had virtually nothing to do with their breeding. Two variables have been constructed.

1) HYV1 = the percentage hectares of HYV wheat and HYV (IRRI) rice.

2) HYV2 = the percentage hectares of HYV wheat and HYV rice weighted by their yearly procurement market prices.

ED_t = the educational level of farmers in Pakistan as represented by the literacy rate of rural males, ages 20-24 years old.

W_t = the effect of weather conditions as represented by rainfall. Two variables have been constructed.

1) W1 = annual rainfall in millimeters.

2) W2 = the deviation from the mean of annual rainfall.

4.2 The Productivity Model with Research and Extension as a Stock Variable

Equation 4.1 is transformed into the logrithmic form as shown in equation 4.2 for the purposes of estimating the parameters.

$$\ln P_t = \alpha_1 \ln \sum_{i=1}^{10} RS1_{t-i} + \alpha_2 \ln \sum_{i=0}^{10} E1_{t-i} + \alpha_3 \ln HYV_t + \alpha_4 \ln ED_t + \alpha_5 W_t + e_t \qquad (4.2)$$

The model represented by equation 4.2 was estimated using OLS with data for the period 1959-60 to 1978-79 (Table B-1). Table 4.1, model I shows the estimated parameters using productivity index PI1 as the dependent variable. The model proves to be less than satisfactory. It is expected that all the signs on the estimated coefficients would be positive however, RS1 exhibits a negative sign. Also the

Table 4.1 Productivity Model Parameter Estimates: RS1 And EX1 as Stock Variables.

Explanatory Variable	PRODUCTIVITY MODELS I	II	III	IV
CONSTANT	-0.971 (-0.14)	0.970 (-0.31)	2.326 (4.80)*	2.810 (7.84)*
ED	0.762 (0.96)	0.397 (0.49)	-	-
HYV1	0.028 (2.34)+	0.027 (2.32)+	-	0.028 (3.30)*
W1	0.0002 (1.39)#	0.0002 (1.11)	0.0002 (1.00)	-
RS1	-0.315 (-0.74)	-0.045 (-0.10)	0.049 (0.17)	0.221 (1.01)
EX1	0.618 (2.01)+	0.444 (1.39)#	0.468 (1.50)#	0.225 (1.01)
D65	-	-0.089 (1.47)#	-0.101 (-1.68)#	-0.113 (-2.06)+
ADJUSTED R^2	.903	.910	.902	.913
D.W.	1.02	1.56	1.52	1.68
D.O.F.	14	13	14	15

T-Statistics are within parentheses.
D.W. is the Durbin-Watson 'd' statistic.

* Significant at the 1. percent level.
\+ Significant at the 5. percent level.
\# Significant at the 10. percent level.

estimated coefficients are not significantly different from zero for ED and RS1 at the 10 percent level.

A dummy variable (D65) was added to model II to capture the effect of the Pakistan-India war and although significant at the 10 percent level, model II is not an improvement over model I.[1/]

A look at the simple correlation matrix of the variables (Table B.2) indicates a possible problem of multicollinearity. The four variables RS1, W1, ED and EX1 are all very highly correlated. Using Klein's rule[2/] (Maddala, p. 185) as a guide in detecting multicollinearity, it was found that $R^2_{PTI} = .93$ (in model I) was less than $R^2_{ED} = .98$; $R^2_{HYV1} = .94$, $R^2_{RS} = .98$ and $R^2_{EX1} = .95$ respecpectively.

Although the best remedy for a multicollinearity problem is more data, this solution is not available to the problem here. Research and extension expenditures are not available previous to 1947-48 and the construction of the education variable previous to 1959-60 is limited. Another method is that of first differences (Maddala, p. 192). Knowing that the use of this corrective measure invites

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1/ Dummy variables to capture the 1971-72 Pakistan-Bangladesh conflict, the 1973-74 Tarbella dam problem which resulted in a lower than normal irrigation water flow, and the 1977-78 wheat rust epidemic were also tried in model II and other models. The estimated coefficients were either of the wrong sign or not significantly different from zero.

2/ Klein's rule of thumb for judging if multicollinearity is a problem is where $R^2_y < R^2_i$, where $R^2_y = R^2_{y \cdot x_1 \cdot x_2 \cdot x_k}$ and $R^2_i = R^2_{x_i \cdot \text{other } x\text{'s}}$ (Maddala, p. 185).

problems of autoregression in the disturbances, a first-differences model was estimated but with less than satisfactory results.[3/]

Another avenue to pursue is to rethink the model specification as set out by Lu et al. With respect to the education variable ED, its effect on increased productivity may indeed be small and not significantly different than zerro. The overall literacy rate in Pakistan only increased from 21.7% in 1971-72 to 24% in 1979-80 (Pakistan Economic Survey, p. 147). For the same period the literacy rate of rural males ages 20-24 increased from 31.1% to only 34.8%. Not only is this a small increase, but the increase is biased upward for our purposes because the rural category includes medium size towns whose occupants would receive more education than the more remote villages where the majority of farmers live. The dropping of ED did little to improve model III. When W1 is also dropped (model IV), the estimated coefficients all have the correct positive signs however RS1 and EX1 are not significant even at the 10 percent level.

To this point, extension variable EX1 has been used in the analysis. As outlined in Appendix B, EX1 includes conventional field assistant extension expenditures along with expenditures on seed multiplication and distribution and farm field trial work by PARC and

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3/ Other models were estimated (but not reported) using HYV2, W2, and the Solow productivity index PI2 without substantial difference in the results. All the models presented in this chapter were estimated alternatively with PI1 and PI2 as the dependent variable. Only results using PI1 are reported in this chapter. Results using PI2 were similar to those using PI2 but very slightly inferior with respect to R^2 and t-tests.

donor agencies. The discussion on conventional extension in Chapter 2 suggests that it has a minimal impact on agricultural productivity. Thus, an extension variable EX2 was constructed (Appendix B) that includes all but conventional expenditures on extension. Substituting EX2 for EX1 in the previous models did not, however aleviate the multicollinearity problems. RS1 and EX2 are also highly correlated resulting in models similar to models I to IV.

Since RS1, EX1 and EX2 are so highly correlated (.98) so as not to permit the estimation of their individual parameters, an option is to combine RS1 and EX1 into one variable as done in many previous studies of this type including the study by Lu *et al.*[4/]

Two new variables were created as a result of the multicollinearity problems and discussion on extension; the combined research and extension variable RSEX1 = RS1 + EX1 which includes conventional extension expenditures and RSEX2 = RS1 + EX2 which excludes conven-

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4/ Maddala, (p. 190) also suggests the use of 1) dropping variables (COV and WTD estimators), 2) ridge regression, 3) principle components and 4) extrainious information. No suitable extrainious information exists and the other solutions as stated by Maddala are limited and mainly of a purely statistical nature.

tional extension expenditures.[5/]

If the premise that conventional extension expenditures do not significantly add to increased productivity, then it would be expected that the rate of return on investments in R & E excluding conventional extension would be higher than the rate of return when conventional extension was included.

Models V to XIII in Tables 4.2 and 4.3 show the results with RSEX2 with and without the weather variable W1. Models V and VI show W1 to be not significantly different from zero. Models IV to VII show the results with RSEX1 again with and without the weather variable W1. W1 is shown to be statistically significant at the 10 percent level in Models IX and X. Although not reported, models were also estimated using HYV2, W2 and PI2 but with similar results. In all the models, the weather variable has presented a problem. The problem may stem from one or all three of the following. First, W1 is highly

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5/ Davis (1979, pp. 43-44) suggests that from a conceptual point of view; it is more reasonable to separate research and extension. This is based on the premis that to combine research and extension forces one to accept one of the following untenable positions; 1) research and extension are perfect substitutes (it does not matter in what proportions they are combined) or, 2) research and extension are complimentary inputs but must be combined in fixed proportions. Separation of research and extension expenditures in Davis' study of the USA may seem reasonable because research and extension involve broad research and extension activities including basic long term research and extensive conventional field oriented extension. In this analysis, in particular the R&E variable RSEX2, represents an R&E system that does not do basic research, is not overly broad in its research agenda and the research (mainly varietal improvement) is tied very directly to the extension activities described by extension variable EX2.

Table 4.2 Productivity Model Parameter Estimates:
RSEX2 as a Stock Variable.

Explanatory Variable	PRODUCTIVITY MODELS			
	V	VI	VII	VIII
CONSTANT	2.996 (6.04)*	2.900 (6.15)*	3.118 (7.72)*	2.950 (7.59)*
HYV1	0.043 (4.63)*	0.039 (4.25)*	0.044 (5.08)*	0.039 (4.56)*
W1	0.0001 (0.44)	0.0001 (0.22)	-	-
RSEX2	0.371 (3.86)*	0.396 (4.31)*	0.351 (4.19)*	0.387 (4.78)*
D65	-	-0.117 (-1.73)+	-	-0.119 (-1.83)+
ADJUSTED R^2	.847	.864	.855	.872
D.W.	0.82	1.18	0.92	1.22
D.O.F.	16	15	17	16

T-Statistics are within parentheses.
D.W. is the Durbin-Watson 'd' statistic.

* Significant at the 1. percent level.
\+ Significant at the 5. percent level.
\# Significant at the 10. percent level.

Table 4.3 Productivity Model Parameter Estimates:
RSEX1 as a Stock Variable.

Explanatory Variable	PRODUCTIVITY MODELS			
	IX	X	XI	X11
CONSTANT	2.225 (4.54)*	2.114 (4.71)*	2.656 (6.36)*	2.451 (6.34)*
HYV1	0.030 (6.88)*	0.028 (6.67)*	0.032 (5.08)*	0.029 (6.90)*
W1	0.0002 (1.53)#	0.0002 (1.37)#	-	-
RSEX1	0.480 (5.52)*	0.504 (6.30)*	0.415 (5.27)*	0.454 (6.23)*
D65	-	-0.105 (-2.08)+	-	-0.115 (-2.24)+
ADJUSTED R^2	.909	.925	.902	.921
D.W.	1.07	1.63	1.28	1.69
D.O.F.	16	15	17	16

T-Statistics are within parentheses.
D.W. is the Durbin-Watson 'd' statistic.

* Significant at the 1. percent level.
\+ Significant at the 5. percent level.
\# Significant at the 10. percent level.

correlated (.94) with all the research and extension variables and thus the problem of multicollinearity arises. Secondly, rainfall may not be a good measure of weather effects because it is an average rainfall over all of Pakistan on a yearly basis and is not combined with a temperature variable that accounts for stress periods in the life of a plant. Thirdly, about 70 percent of Pakistan's cropped land is irrigated and 85-90 percent of all wheat production and all rice production are grown on irrigated land (Agricultural Statistics of Pakistan). Thus the variation in overall total yields due to rainfall would be low.

The next section compares the results of using stock variables with that of a distributed lag approach. The rate of return from research and extension using the results of the above stock variable model are found in section 4.4.2.

4.3 The Productivity Model with Research and Extension as Distributed Lag Variable

Equation (4.1) is again transformed into the logarithmic form keeping in mind the discussions on education and the multicollinearity problems between the research and extension variables. Equation (4.3) indicates that the level of productivity is a function of the combined research and extension expenditures expressed as a distributed lag, the introduction of HYV's and the current weather.

$$\ln P_t = \sum_{i=1}^{n} \alpha_i \ln RE_{t-i} + \beta_1 \ln HYV_t + \beta_2 W_t + e_t \qquad (4.3)$$

where:

RE_t = the sum of the research and extension expenditures in year t. Two different variables are used.

1) $RE1_t$ = research expenditures in year t (R_t) plus extension expenditures (includes conventional extension) in year t (E1).

2) $RE2_t$ = research expenditures in year t (R_t) plus extension expenditures (excludes conventional extension) in year t (E2).

and P_t, HYV and W_t are as described in section 4.2.

The combined research and extension expenditure variables are assumed to adopt an inverted "U" shape distribution of the partial production coefficients. This assumption is based on Evenson (1968) and was used by Davis (1979) and Lu et al (1979). The assumption is that expenditures on research and extension will have a small impact on productivity increase in the current year of their expenditure but that the impact increases to a peak over time but then decays. The assumption is also made that the distribution of the partial production coefficients can be expressed as a second degree polynomial with endpoints constrained to zero.

The estimation procedure used to calculate the partial production coefficients (α_i) and the construction of the appropriate research and extension variable which is an Almon polynomial lag procedure follows that of Maddala (1977, pp. 356-359) and Davis (1979, pp. 69-71) and is presented as follows.

A second degree polynomial is given in Equation (4.4) as

$$\alpha_i = b_0 + b_{1i} + b_{2i}^2 \tag{4.4}$$

where $i = 0 \ldots k$ and $i = t = 0$ in the current year (thus $k =$ 1 - the number of years in the lag).

By constraining the endpoints to be zero, that is $\alpha_{-1} = 0$ and $\alpha_{k+1} = 0$ in equation (4.4), we obtain the following relationship

$$b_0 + b_1(-1) + b_2(-1)^2 = 0 \tag{4.5}$$

$$b_0 + b_1(k+1) + b_2(k+1)^2 = 0 \tag{4.6}$$

where Equations (4.5) and (4.6) simplify to:

$$b_0 = -b_2(k+1) \tag{4.7}$$

$$b_1 = -b_2 k \tag{4.8}$$

By substituting (4.7) and (4.8) into (4.4) and then substituting the result into the productivity model of equation (4.3), the following is obtained

$$\ln P = b_2 Z_t + \beta_1 \ln HYV_t + \beta_2 W_t + e_t \tag{4.9}$$

where

$$Z_t = \sum_{i=0}^{k} (i^2 - k_i - k - 1) \ln RE_{t-1} \tag{4.10}$$

The model in Equation (4.9) is then estimated to obtain b_2 which is then substituted into Equations (4.7) and (4.8) to obtain b_o and b_1. Equation (4.4) is then used to obtain the partial production coefficients (α_i), the sum of which represent the total production elasticity.

The model in Equation (4.9) was estimated by OLS again for the period 1959-60 to 1978-79 using an 8, 10 and 12 year lag. The models estimated with the arithmetic productivity index PI1 and the 10 year lag are presented. The 8 year lag models are statistically inferior and although the 12 year lag models are statistically similar to the 10 year lag models, the rate of return results as discussed in section 4.5 are not consistant. Also, since the construction of the R & E stock variable is based on a 10 year lag, the rates of return would be more comparable between the two approaches.

Davis (1979) used a 14 year lag and Lu et al (1979) determined statistically that a 13 year lag on R & E expenditures were appropriate for the United States. A shorter lag of 10 years for Pakistan would seem appropriate because of the type of research that is conducted. Pakistan's R & E agenda does not involve much basic research but rather involves the adaptation of segregating materials received mainly from international centers and seed multiplication and transfer activities.

Table 4.4 summarizes the results of three distributed lag (10 year) productivity models using research and extension expenditure RE2 (excluding conventional extension). The weather variable again is not statistically significantly different from zero. Table 4.5 summarizes the results using research and extension expenditures RE1 (including conventional extension). The weather variable is significantly different from zero at the 10 percent level in model IV but not in model

Table 4.4 Distributed Lag Model Parameter Estimates: RE2 as The Research-Extension Variable.

Explanatory Variable	Distributed Lag Models (10 Year Lag) I	II	III
CONSTANT	1.645 (1.94)+	1.488 (1.84)+	1.730 (2.61)+
HYV1	0.052 (7.72)*	0.049 (6.23)*	0.050 (6.54)*
W1	0.0001 (0.74)	0.0001 (0.55)	-
D65		-0.112 (-1.64)#	-0.117 (-1.76)+
Distributed Lag Weights (RE2).			
0	.015	.016	.015
1	.027	.029	.027
2	.036	.038	.036
3	.042	.045	.042
4	.045	.048	.045
5	.045	.048	.045
6	.042	.045	.042
7	.036	.038	.036
8	.027	.029	.027
9	.015	.016	.015
Sum of Weights	.330 (3.86)*	.352 (4.24)*	.330 (4.64)*
ADJUSTED R^2	.847	.862	.867
D.W.	0.76	1.13	1.20
D.O.F.	16	15	16

RE2 is the Research-Extension variable excluding conventional Extension expenditures.
T-Statistics are within parentheses.
D.W. is the Durbin-Watson 'd' statistic.
* Significant at the 1. percent level.
+ Significant at the 5. percent level.
# Significant at the 10. percent level.

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Table 4.5 Distributed Lag Model Parameter Estimates: RE1 as The Research-Extension Variable.

Explanatory Variable	Distributed Lag Models (10 Year Lag)		
	IV	V	VI
CONSTANT	0.734 (0.83)	0.593 (0.70)	1.224 (1.71)#
HYV1	0.036 (8.59)*	0.035 (8.25)*	0.035 (8.29)*
W1	0.0003 (1.50)#	0.0002 (1.33)	-
D65	-	-0.094 (-1.63)#	-0.105 (-1.80)+
Distributed Lag Weights (RE1).			
0	.019	.019	.017
1	.034	.035	.030
2	.045	.046	.040
3	.052	.054	.047
4	.056	.058	.050
5	.056	.058	.050
6	.052	.054	.047
7	.045	.046	.040
8	.034	.035	.030
9	.019	.019	.017
Sum of Weights	.412 (4.76)*	.424 (5.16)*	.368 (4.32)*
ADJUSTED R^2	.891	.901	.897
D.W.	1.07	1.49	1.44
D.O.F.	16	15	16

RE1 is the Research-Extension variable including conventional Extension expenditures.
T-Statistics are within parentheses.
D.W. is the Durbin-Watson 'd' statistic.
* Significant at the 1. percent level.
+ Significant at the 5. percent level.
# Significant at the 10. percent level.

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To test the appropriateness of imposing the constant of zero endponts, Equation (4.3) was also estimated without endpoint constraints (Maddala, 1977, p. 357). An F statistic was then used to test the null hypothesis that the endponts are equal to zero. The F statistic is as follows

$$F_{m,n-k-1} = \frac{(e'e - e'_1e_1)/m}{e'_1e_1/(n-k-1)} \tag{4.11}$$

where e'e is the residual sum of squares from the restricted model, e'_1e_1 is the residual sum of squares obtained from the unrestricted model, m is the number of endpoint constraints, n is the number of observations and k is the number of independent variables (Lu et al, 1979, p. 21).

The calculated F value using Equation (4.11) for model III and model VI do not reject the null hypothesis that the endpont constraints are zero at the 1-percent level. For example the calculated F value for model VI is 5.95 and under the table value of 6.51.

4.4 The Rate of Return to Research and Extension in Pakistan

The rate of return to R & E in Pakistan can be calculated using the information from the previously estimated models in sections 4.2 and 4.3. The procedure for finding the rate of return differs between the distributed lag model and the stock variable model because of the difference in the construction of the R & E variables used in each case. Despite this, it would be expected that the two approaches would produce similar results.

It would also be expected, as expressed in section 4.2 that the rate of return on investments in R & E excluding conventional extension would be higher than the rate of return when conventional extension was included.

4.4.1 Rate of Return from the Distributed Lag Model

Since a double-log function was used to estimate the parameters of Equation (4.3), the partial production coefficients are elasticities and their sum the total production elasticity. The marginal product of the research and extension variable (RE) for each year in the lag is given as:

$$MP_{t-i} = \alpha_i \frac{\overline{P}}{\overline{RE}}; \quad i = 0 \text{ to } k \tag{4.12}$$

where $\overline{P}$ and $\overline{RE}$ are the average of the productivity index P and the research and extension variable RE. It is however, the value of the marginal product that is required thus each annual marginal product in the 10 year lag must be multiplied by the value of one unit of productivity index P. This is done as follows (Lu et al, 1979, pp. 28-29 and Cline, 1975, pp. 90-94):

$$VMP_{t-i} = \alpha_i \frac{\overline{P}}{\overline{RE}} \cdot \frac{\Delta Y_t}{\Delta P_t} \tag{4.13}$$

where ΔY_t is the change in the value of output net of the change in the value of inputs and ΔP_t is change in the productivity index bet-

between years.[6/] Thus $\Delta Y_t/\Delta P_t$ is the value (price) of one unit of productivity index.

Using equation (4.12) and the distributed lag coefficients from the distributed lag model III (excludes conventional extension) and model VI (includes conventional extension), the total marginal products summed over the 10 year lag are 3.04 and 2.42 respectively. In the first case, this means that a million RS investment in research and extension expenditures (RE2) will increase the productivity index by 3.04 points over a 10 year period.

A calculation of the value of the marginal products summing Equation (4.13) over the 10 year lag indicates a VMP of Rs 6.09 for model III and a VMP of Rs 4.85 for model VI. In the first case, this means that an investment of Rs 1.00 in R & E expenditures will yield a return of RS 6.09 over the 10 year period. However because the returns (VMP's) are distributed over time, a better indication of the returns to the investment would be to discount the VMP's to a present value (PV).[7/] Given the discount rates (r) of 5, 10 and 15 percent,

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6/ To be more precise, the basic equation used to calculate an arithmetic productivity index P is given by:
$P_1 = [V_1/(r_0K_1+w_0L_1]/[V_0/(r_0K_0+w_0L_0)]$ where; V = the value of output, K = the physical quantity of capital, L = the physical quantity of labor and $r = VMP_K$, $w = VMP_L$ representing the price of capital and labor respectively (see Lu *et al*, 1979, pp. 6-7 and Cline, 1975, pp. 91-94 for the derivation of the arithmetic productivity index to this point). Thus $\Delta P = P_2 - P_1$ and $\Delta Y = V_2 - V_1 - [(r_0K_2 + w_0L_2) - (r_0K_1 + w_0L_1)]$.

7/ $PV = \sum_{i=0}^{k} (VMP_{t+i}/(1 + r)^i)$

the PV of a Rs 1.00 investment in research and extension for model III will yield Rs 4.93, Rs 4.08 and Rs 3.44 respectively. Using the same discount rates for model VI yields Rs 3.92, Rs 3.24 and Rs 2.74 respectively for a Rs 1.00 investment in research and extension.

In keeping with the conventions of other studies of this type, a marginal internal rate of return (MIRR) is calculated using the following formula;

$$1 - \sum_{i=0}^{k} \frac{VMP_{t+i}}{(1+r)^{i}} = 0 \qquad (4.14)$$

and is that discount r which equates the discounted future returns with the initial investment.

Performing the calculations, the MIRR in the case of model III (excluding conventional extension) is 85.6 percent. The MIRR for model VI (including conventional extension) is 64.5 percent. Similar calculations using the partial production coefficients from models I and II and models IV and V result in equal or higher MIRR's when compared with models III and VI respectively.

4.42. Rate of Return from the Stock Variable Model

The rate of return to research and extension when used as a stock variable is the same as the calculation of the rate of return of a capital stock variable in a production function. That is, the value of the marginal product represents the rate of return on the investment. The VMP of research and extension is calculated using equation (4.15).

$$VMP = \alpha \frac{\overline{P}}{\overline{RSEX}} \cdot \frac{\Delta Y}{\Delta P} \qquad (4.15)$$

Using the coefficient on RSEX2 (excludes conventional extension) from productivity model VIII in Table 4.2, the rate of return is 77.6 percent. Using the coefficient on RSEX1 (includes conventional extension) from productivity model XII in Table 4.3, the rate of return is 56.2 percent.[8/] The average value of $\Delta Y/\Delta P$ over the 20 year period is about 2.0 million Rs.

4.5 Summary and Discussion

Two different productivity models were estimated, one using a second degree polynomial distributed lag of the R & E expenditures as the research variable and as the second, a stock variable of R & E expenditures. The separate research and extension expenditures were combined into a single variable because of multicollinearity problems. A discussion in section 4.2 of the extension activities led to constructing two different types of R & E variables; 1) an R & E variable that included conventional extension expenditures and 2) an R & E variable that excluded conventional extension expenditures.

The calculations of the rates of return to the direct investment in the Pakistani agricultural research and extension system are summarized in Table 4.6.

8/ VMP(VIII) = 0.387 x (120.4/120.4) x 2.0 = .774
VMP(XII) = 0.454 x (120.4/194.5) x 2.0 = .562
where $\overline{P}$ and $\overline{RSEX}$ are the geometric means.

Table 4.6 Summary of Rates of Return to Research and Extension Investments.

	Distributed Lag Model	Stock Variable Model	Present Value of Rs. 1.00 Investment at Varies Discount Rates ‡			
			0.0	0.05	0.10	0.15
	(Percent			(Rupees)		
Model A						
R&E Excluding Conventional Extension	85.6	77.4	6.09	4.93	4.08	3.44
Model B						
R&E Including Conventional Extension	64.5	56.2	4.85	3.92	3.24	2.74

‡ Based on estimates from the Distributed Lag Model.

The rate of return figures in Table 4.6 are large but within the bounds of what might be expected based on returns from similar analysis of other countries. For example, Barletta's study on Mexico (45-93 percent) and Kahlan, Bal, Saxena and Jha's study on India (63 percent) indicate similar results (Ruttan, 1982, p. 243).

The rates of return in Table 4.6 are the returns to incountry investment in the research and extension system of Pakistan by federal and provincial governments, PARC and donor agencies. It is not possible to examine the rate of return to individual contributors separately. Also, the rates of return do not include expenditures for research done at international centers. If Pakistan had to support international centers such as CIMMYT and IRRI in proportion to the benefits they receive (i.e., genetic material), the rate of return would be much lower. Unfortunately, the type of information needed to calculate such a rate of return is not available. In this analysis, support from international agencies are looked upon as a free good. Thus the rate of return figures in Table 4.6 can be looked upon by the individual contributors to the Pakistan agriculture research and extension system as an overall average (marginal) return that might be expected from a broad based research and extension agenda.

Since the rate of return figures for both the distributed lag model and the stock variable model are essentially marginal internal rates of return, it was expected that they would be similar in magnitude. As Table 4.6 indicates, the rates of return are not exactly the

same but are within about 10 percent of each other in both models A and B.

It was also expected that the rate of return calculated from both the distributed lag model and the stock variable model would be higher on investments in R & E excluding conventional extension than the return on R & E including conventional extension. Table 4.6 does bear this out for both the distributed lag model and the stock variable model.[9/]

Other researchers, Peterson (1967), Evenson (1968), Lu et al, (1979) have adjusted their results to take account of private industry R & E and R & E from other sources. Although small pockets of private research exist such as Rafhan Maize Co.'s research on hydrid maize, their overall impact is very small (Pray, 1982). The HYV introduction variable was used to account for other sources of R & E that the Pakistan research system had not contributed to. Thus, it is claimed that the VMP's from the estimated models come from R & E investments by the principle contributors to R & E as described in Appendix B. However, if one were to suppose that only two-thirds of the MVP could be claimed by the principle contributors to R & E, the rates of return would still be very high. For model A (excluding conventional

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9/ Rates of return were calculated for the 12 year distributed lag model and were 38.7 percent for model A (excluding conventional extension) and 53.4 percent for model B (including conventional extension). As noted, the magnitudes of the rates of return are in reverse order to that of the 10 year distributed lag model and the stock variable model.

extension), the rates of return for the distributed lag model would be 53 percent and 52 percent for the stock variable model. For model B (including conventional extension), the rates of return for the distributed lag model would be 39 percent and 37 percent for the stock variable model.

CHAPTER 5

Summary, Conclusions and Observations

5.1 Summary

The main objectives in this study were first, to describe the agricultural environment within which it operates. Secondly, an objective was to obtain empirical estimates of the benefits and rates of return to investments in the agricultural research and extension system. A third objective was to look at the distributional effects from the adoption of HYV's.

Chapter 1 described Pakistan's economy with special reference to the agricultural sector. The agricultural sector is the dominant sector of the Pakistan economy contributing to 30.0 percent of total GDP and employing 55 percent of the work force as well as directly accounting for 48 percent of foreign exchange earnings. The prominent position that agriculture plays in Pakistan's economy makes agriculture a focal point around which programs can be built to foster economic growth and development.

Pakistan's present 3.0 percent annual population growth rate growth rate combined with a moderate rise in per capita income and the need for foreign exchange earnings puts a heavy demand on the agricultural sector. At present, the annual growth rate of food and fiber crops is 3.5 percent, however, the growth rate in beef production is 1.2 percent. To avoid large food import bills and balance of payments problems in the future would require growth rates in excess of those at present. To accelerate the present agricultural output growth rate requires a larger commitment to Pakistan's agricultural development model.

Chapter 2 described various agricultural development models and in particular described a science-based agricultural model that relies on the physical and biological sciences, management sciences and social sciences to produce and disseminate new technologies and guide institutional development. The experiences with a science-based agricultural development model have been favorable in developed countries, but while Pakistan essentially pursues a similar development model, it has met with less than complete success.

The further removal of biological and socioeconomic constraints that are present in the Pakistan agricultural system have been inhibited by the inability to fully commit the necessary resources. Low funding levels, inadequate numbers of trained professionals as well as inadequate equipment and facilities have constrained the research and extension efforts. Agricultural output and productivity have also been constrained by the input and product markets. Science-based agricultural inputs such as fertilizer, HYV seed, herbicides and pesticides are not always available in the desired quantities or time periods because of an immature input marketing and distribution system. Low product-input price ratios have militated against a more intensive use of inputs and the development of a more mature input marketing system which has resulted in lower than desired agricultural output growth rates.

Chapter 3 empirically estimated the benefits and rates of return to investments in wheat and maize research and extension. The index number approach was used measuring the change in consumer surplus and

producer surplus from a rightward shift in the supply curve due to the adoption of HYV seeds. Yield advantage figures used in the calculation of the supply shifter were obtained from On-Farm Yield Constraints trial data for both wheat and maize. The yield advantage figures were weighted by the proportion of HYV to total area sown in developing the supply shifter. With respect to wheat, only those HYV areas sown to HYV's developed by a Pakistan/CIMMYT collaboration were included. Thus, HYV introductions from other countries that Pakistan did not contribute to were not included in the calculations of the benefits.

The perfectly competitive, free trade index number approach model was modified in the case of wheat to include provisions for government price intervention and import policies and home consumption. The maize index number model only required the addition of a home consumption demand.

Annual benefits from the adoption of both wheat and maize HYV's were calculated once the annual prices and quantities, supply and demand elasticities, annual supply shifter and home consumption demand were made available. The annual stream of benefits for both wheat and maize were then related to their associated annual stream of research and extension costs. External, internal and marginal rates of return were calculated for each crop. For wheat, the internal rate of return ranged from 55 to 71 percent and the marginal rate of return ranged from 60 to 85 percent depending on the scenario. The internal rate of return to research and extension investments in

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maize were 17 to 25 percent and the marginal rate of return ranged from 18 to 26 percent for all Pakistan. Internal rates of return of maize were 17 to 25 percent and the marginal rate of return ranged from 18 to 26 percent for all Pakistan. Internal rates of return of maize in the provinces of the Punjab and N.W.F.P. ranged from 18 to 27 percent and 19 to 24 percent respectively.

The rates of return calculated in this study treated the support from international agencies as a free good. Thus, the rate of return figures are to be looked upon by individual contributors to the Pakistan agricultural research and extension system as the returns that may be expected from a broad based research and extension agenda for each crop. An analysis of the rate of return to wheat research and extension had Pakistan purchased the total services of CIMMYT resulted in a rate of return of 28 to 30 percent. A further analysis indicated that the loss in monetary terms to the wheat rust epidemic in 1977-78 was at least four and one-half times the amount spent on the entire agricultural research and extension system for that year.

A limited analysis was conducted on the distributional effects between consumers and producers from the adoption of HYV maize. Benefits were calculated for consumers as a group as well as changes in producer revenues and production costs. It was found that the correct specification of the supply and demand elasticities and marketable surplus ratios were very important because the distributional effects are very sensitive to small changes in these parameters.

While consumers always gained, small changes in the elasticities and marketable surplus ratios would result in changing the producers income situation from negative to positive or vica-versa. Lack of good sound data precluded a rigorous analysis of the distributional effects between various other groups.

Chapter 4 empirically estimated the overall returns to all agricultural research and extension expenditures in Pakistan. The analysis took the form of estimating an equation portraying a Pakistan total factor agricultural productivity index as a function of weather, education, research and extension expenditures and a variable to account for HYV introductions. Due to multi-collinearity problems research and extension expenditures were combined into a single variable. Two forms of the research and extension variable were used. The first was as a stock variable and the second was as a 10-year second degree polynomial distributed lag variable. The overall marginal rates of return from the two models were very close. When all research and extension expenditures are included, the marginal rates of return were calculated to be 64.5 and 56.2 percent for the distributed lag model and the stock variable model respectively.

5.2 Conclusions and Observations

The following conclusions and observations in point form follow both from the empirical findings of this study and from the descriptive analysis and background investigations into the Pakistan agricultural system.

1. Pakistan must not only sustain its present agricultural output growth rate but must increase it if the country is to avoid large food import bills and balance of payments problems. The blueprint exists to achieve the required growth rate in agricultural output in terms of a science-based agricultural development model. This model to some extent is pursued by Pakistan but not with the commitment necessary to achieve the required growth rates. Higher levels of funding, manpower training and organizational skills are required in both the agricultural research and extension areas as well as institutional changes in the input and product markets. Without such a commitment, Pakistan will not only fail to achieve higher output growth rates but may even fail to sustain agricultural growth rates at their present level.

2. The science-based agricultural model of development requires a strong integrated agricultural education, research and extension system. Pakistan's agricultural model, however, cannot be characterized as being 'integrated.' The linkages between the agricultural education, research and extension system are weak. It may be the appropriate time to reunite the research institutes and the university education programs into an integrated research-education institute and forge new linkages with the existing extension systems.

3. In observing the Pakistan agricultural research system it is somewhat disconcerting that most of the initiative comes not from within the Pakistani system itself but from the outside. Donor agencies such as USAID and the international research institutes such as

CIMMYT and IRRI provide the impetus behind the more successful wheat, maize and rice programs. Those commodity research programs that are not backed up by a strong incountry international institute program such as the pulse crops or livestock are very weak. The concern is if the outside initiative is cut off, many of the successful programs would collapse. A further concern is that outside initiative by itself cannot develop the full potential of the Pakistan agricultural research system.

4. A strong incountry presence by an international institute may focus a recipient country's research resources and attention to those commodities of the international institute at the expense of an equally important crop. For example, gram is an important crop in the diet of many Pakistanis and overall more important than maize. Yet maize has received a larger share of Pakistani research resources than gram. The gram research program is not affiliated with a strong incountry presence of an international institute and gram yields have notably stagnated, if not decreased, over the years. Although not known, funds spend on gram research equal to that of maize may have equalled or bettered the rate of return to maize.

5. It seems apparent that it is not enough for international institutes to just exist but that they also have a strong incountry presence when working with recipient countries. The incountry presence should be in a form that somewhat resembles a farming systems unit that collaborates with other international institutes and the recipient country's research system. This is evidenced by the greater

success of the wheat and maize programs in Pakistan relative to the success of most other research programs. The strong CIMMYT incountry presence that comprises a wheat agronomist, maize breeder and now an economist provides the necessary leadership for a successful program.

6. While the overall Pakistani research and extension system requires strengthening, the two areas of the extension component itself and the livestock component within the research and extension system receive less attention. It may be prudent to focus on crop specific commodity research which give the fastest and largest returns in the initial stages of an agricultural development program, however, it may be time that equally attractive gains can be made from the strengthening of the extension system as well as the livestock programs.

7. The prominence of international research institutes and the ability to import varieties from other countries have the appearance that a country can be a free rider and not invest in its own research capabilities. Aside from the danger of importing weed seeds and diseases not common to your country, Pakistan's experience with the wheat rust epidemic on the surface indicated that it could indeed import HYV seed and get away with it. However, the imported seed was no better than Pakistan's best rust resistant varieties and it was the knowledge from the Pakistani research system that enabled the fairly swift and decisive action in obtaining the best available seed. Without the internal research capacity, Pakistan would never have rebounded to normal production levels the very next year. There are

also no assurances of quality or timeliness of seed imports and as in the case of gram blight, the luxury of importing better varieties did not exist. Production statistics indicate that gram production did not rebound to normal levels in the years following the gram blight. The above reasons combined with the knowledge that most technology is location specific suggests the need for strong in country research capabilities.

8. The empirical results indicate that despite existing problems in the Pakistan agricultural system, the expenditures on agricultural research and extension pay a favorable rate of return. The marginal rates of return to investments in wheat research and extension of between 60 to 85 percent and to maize research and extension of 18 to 26 compare favorably with rates of return from similar studies done in other countries. The overall rate of return between 55 and 65 percent to all expenditures on agricultural research and extension in Pakistan also compare favorably. With the knowledge that Pakistan's research, education and extension system is underfunded and understaffed relative to other country research, education and extension systems, the high rates of return may also suggest that the agricultural research and extension system is underfunded. Economic principles dictate that investments in a particular enterprise should continue until the rate of return is equal to the returns to investments in other enterprises. Unfortunately, a full range of rate of return figures for all investments in Pakistan is not available. However, given the magnitude of the rate of returns, it is unlikely

that there are many alternatives. One can easily come up with existing investments such as the Karachi steel mill or the Karachi nuclear power plant that would not begin to approach the rates of return to agricultural research and extension.

To end on an optimistic note, Pakistan, gifted with the largest irrigation system and some of the best land in the world, has the potential to increase its agricultural output and productivity. The recent strengthening of the Pakistan Agricultural Research Council (PARC) with its collaboration with donor agencies and international institutes shows signs of taking more initiative in the developing of Pakistan's agricultural development model. The past few years has seen increased numbers of scientists being trained along with the establishment of the National Agricultural Research Center (NARC) and an effort to coordinate research and extension programs. The recent project to integrate research and teaching at the agricultural university in Peshawar is also a promising venture.

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APPENDIX A

Wheat and Maize Research and Extension Expenditures

Provincial and Federal research expenditures on wheat and maize are given by Province in Table A-1. The expenditures were obtained from the directors of the provincial agricutural research institutions in each of the four Provinces. The institutes in the Punjab, Sind, N.W.F.P. and Baluchistan are the Punjab Agricultural Research Insitute, Faisalabad, Agricultural Research Institute, Tandojam, Agricultural Research Institute, Tarnab and the Agricultural Research Institute Sariab, Quetta respectively. Some of the earlier year data was not available and the earliest known data used in its place. The earliest available Baluchistan data is 1976-77 and rough estimates are used for previous years.

Maize cultivation and therefore research occurs mainly in the Punjab and N.W.F.P. A minimal amount of maize research occurs in Sind and Baluchistan thus the expenditures are not reported.

The expenditures in Table A-1 are basically research expenditures and do not include experimental farm extension activities. For the analysis, the totals in Table A-1 for both wheat and maize are doubled to take into account the experimental farm extension activities.

Several other sources from which wheat and maize expenditures were extracted are given in Table A-2. The objective is to include both research and extension, in particular that form of extension involving seed multiplication and transfer. From the discussion on extension in Chapter 2, it was felt that conventional field assistance

Table A-1. Provincial and Federal Research Expenditures On Wheat and Maize.

Year	Wheat Research Expenditures					Maize Research Expenditures				
	Punjab	Sind	NWFP	Baluch.	Total	Punjab	Sind	NWFP	Baluch.	Total
	(000's Current Rs.)									
1960-61	370	117	65	50	552	194	-	45	-	239
1961-62	370	117	65	50	552	194	-	45	-	239
1962-63	370	117	65	50	552	194	-	45	-	239
1963-64	251	117	72	50	490	194	-	155	-	349
1964-65	285	117	74	100	576	273	-	203	-	476
1965-66	339	117	119	100	675	302	-	229	-	531
1966-67	243	118	154	100	615	382	-	134	-	516
1967-68	225	123	147	100	595	392	-	147	-	539
1968-69	253	132	183	150	718	382	-	163	-	545
1969-70	342	154	220	150	866	456	-	202	-	658
1970-71	547	146	484	150	1327	432	-	417	-	849
1971-72	564	145	205	150	1064	761	-	248	-	1009
1972-73	704	155	327	200	1386	882	-	466	-	1348
1973-74	618	155	375	200	1348	1050	-	773	-	1823
1974-75	693	196	379	200	1468	1395	-	745	-	2140
1975-76	961	279	496	200	1936	1579	-	632	-	2211
1976-77	837	184	504	250	1775	1576	-	776	-	2352
1977-78	1094	197	435	350	2076	1466	-	853	-	2319
1978-79	1156	324	457	421	2358	1137	-	771	-	1908
1979-80	2412	356	441	374	3583	1170	-	1010	-	2180
1980-81	1640	335	889	430	3294	1500	-	1136	-	2636
1981-82	1673	379	765	589	3406	1646	-	1006	-	2652

SOURCE: See Text of Appendix A for description and source of data.

Table A-2. Research and Extension Expenditures By Source In Thousands of Current Rs.

Year	Extension Expenditures: Including Conventional Extension (E1)	Extension Expenditures: Excluding Conventional Extension (E2)	AEARC	NIAB	PARC	USAID/FORD PL-480	Pirsabak
	(000's Current Rs.)						
1960-61	8427	3918	23	-	-	-	-
1961-62	14455	9328	23	-	-	-	-
1962-63	13607	5279	160	-	-	-	-
1963-64	18123	3865	208	-	-	-	-
1964-65	21588	5046	91	-	-	-	-
1965-66	14982	5193	103	-	-	-	-
1966-67	17753	7244	114	-	-	-	-
1967-68	17341	7028	117	-	-	-	-
1968-69	17548	5247	113	-	-	-	-
1969-70	16280	4000	167	-	-	-	-
1970-71	20239	4486	166	-	-	66	-
1971-72	16232	3672	158	-	-	510	-
1972-73	18360	3796	211	-	-	710	-
1973-74	35186	11528	249	-	2702	3333	63
1974-75	46631	15456	308	467	14528	6381	345
1975-76	93762	28608	487	567	28466	8288	140
1976-77	116461	52784	542	762	17435	8862	1125
1977-78	133768	72190	564	835	20112	13620	1685
1978-79	138899	64375	629	1239	21491	15884	690
1979-80	242952	130588	448	1356	31849	19345	476
1980-81	279395♦	150176♦	820	1473	52645	16288	780
1981-82	321304♦	172703♦	1090	1467	122822	22823	93

SOURCE: See Text of Appendix A for description and source of data.
♦ Estimate.

extension added little to increased productivity. Thus two different extension expenditure categories are constructed as follows: 1) E1, which includes conventional extension, and 2) E2, which excludes conventional extension. The construction and sources of the extension expenditures are to be found in Appendix B.

Since the extension expenditures in Table A-2 are total Pakistan figures for all crops and livestock, it is difficult to accurately assign the proportion of expenditures to wheat and maize. When done on the basis of the percentage total acreage sown of a crop to total sown acreage of all crops, the proportions would be 35 percent wheat and 5 percent maize.

Other expenditure sources for wheat and maize are the Atomic Energy Agricultural Research Centre (AEARC), Tandojam and the National Institute of Agricultural and Biology (NIAB), Faisalabad. The expenditures for the two centres were obtained from the Directors. Research is done about equally on about five to six crops at both centres; however, little maize research is done at AEARC. Thus, 20 percent of the total figures of the AEARC and the NIAB in Table A-2 will be proportined to wheat and 20 percent of NIAB to maize.

The construction and sources of data for PARC, USAID/FORD/PL-480 and Pirsabak are contained in Appendix B. The proportion of expenditures for wheat and maize from the PARC and USAID/FORD/PL-480 sources are the same as that for extension with the exception that maize expenditures are 35 percent of the USAID/FORD/PL-480 source. This reflects the committment of having in-country a full-time maize breeder. The

Pirsabak expenditures are split evenly between wheat and maize.

Table A-3 includes the overall current and constant 1959-60 expenditures on wheat and maize. The current figures are added together from Tables A-1 and A-2 in the manner described above. The constant 1959-60 figures are obtained by using two deflators. The first is a capital goods import deflator (D1) and the second is an index of wages in agriculture (D2). The two deflators are described in Appendix B and are presented in Table B-6.

The current expenditures in Tables A-1 and A-2 are deflated in the following way. Total wheat and maize expenditures in Table A-1 are deflated by using D1 on 40 percent and D2 on 60 percent of the totals. E1 in Table A-2 is deflated using D1 on 40 percent and D-2 on 60 percent of the total. Sixty percent of E2 expenditures are deflated by D1 and 40 percent by D2. Thirty percent of AEARC, NIAB and PARC expenditures are deflated by D1 and 70 percent by D2. USAID/FORD/PL-480 and Pirsabak expenditures are deflated by D1. The proportion in which the deflators D1 and D2 are used in deflating each expenditure category is based on the background data used to construct the totals and conversations with Directors and scientists on the proportion of the budget spent on salaries and capital items.

Table A-4 includes maize research and extension expenditures for the Provinces of Punjab and N.W.F.P. Current expenditures by province are accumulated from data in Tables A-1 and A-2 in the same manner that they were in constructing the total maize expenditures. Extension, PARC and USAID/FORD/PL-480 expenditures are split fifty-fifty

Table A-3. Wheat and Maize Research and Extension Expenditures, Pakistan.

Year	Wheat Expenditures				Maize Expenditures			
	Including Conventional Extension		Excluding Conventional Extension		Including Conventional Extension		Excluding Conventional Extension	
	Current	1959-60	Current	1959-60	Current	1959-60	Current	1959-60
	(000'S Rs.)							
1960-61	4058	3896	2480	2370	899	863	674	645
1961-62	6168	5080	4373	3562	1200	988	944	772
1962-63	5898	4672	2984	2341	1158	917	741	585
1963-64	7364	5585	2374	1808	1604	1216	891	676
1964-65	8726	6565	2936	2272	2031	1528	1204	915
1965-66	6614	4656	3188	2319	1811	1275	1321	941
1966-67	7466	4974	3788	2647	1919	1279	1394	946
1967-68	7266	4561	3673	2425	1945	1218	1429	913
1968-69	7600	4711	3295	2166	1967	1219	1352	856
1969-70	7463	4752	3165	2147	2130	1357	1516	984
1970-71	9794	6394	4280	2979	2733	1781	1945	1293
1971-72	8019	4673	3623	2222	3008	1730	2380	1380
1972-73	9489	3380	4391	1566	3862	1375	3134	1116
1973-74	17205	3346	8925	1725	6739	1315	5556	1084
1974-75	17205	4648	15991	2760	9837	1702	8278	1433
1975-76	49833	8310	27029	4543	13617	2245	10359	1706
1976-77	54388	8619	32051	5145	15215	2392	12032	1896
1977-78	63899	8821	42347	5963	18109	2455	15030	2048
1978-79	67131	8717	41047	5436	17987	2281	14262	1813
1979-80	111415	13659	71389	9025	25480	3050	19761	2388
1980-81	164351	19032	[illegible]	10060	33259	3781	21799	2500
1981-82	170802	18633	118791	13339	35838	3821	28408	3065

SOURCE: Tables A-1 and A-2 and Text in Appendix A.

Table A-4. Wheat and Maize Research and Extension Expenditures by Province, Pakistan.

Year	Punjab Expenditures				NWFP Expenditures			
	Including Conventional Extension		Excluding Conventional Extension		Including Conventional Extension		Excluding Conventional Extension	
	Current	1959-60	Current	1959-60	Current	1959-60	Current	1959-60
	(000'S Rs.)							
1960-61	599	575	486	466	301	289	188	180
1961-62	749	618	621	509	451	372	323	263
1962-63	728	576	520	410	430	341	222	174
1963-64	841	638	485	368	763	579	407	309
1964-65	1085	817	672	510	946	711	532	405
1965-66	979	689	734	522	833	586	588	419
1966-67	1208	805	945	638	712	475	450	308
1967-68	1218	762	760	610	728	456	470	303
1968-69	1203	746	896	564	765	475	458	292
1969-70	1320	841	1012	655	812	517	505	331
1970-71	1382	901	988	656	1352	881	958	637
1971-72	2017	1166	1703	991	992	563	678	388
1972-73	2348	835	1983	706	1516	539	1152	409
1973-74	3631	708	3039	590	3109	604	2517	488
1974-75	5530	952	4750	816	4308	741	3529	606
1975-76	7778	1280	6149	1012	5840	953	4212	683
1976-77	8203	1287	6611	1039	7013	1093	5421	844
1977-78	9330	1263	7790	1059	8780	1176	7240	972
1978-79	9312	1175	7448	941	8677	1089	6814	854
1979-80	12917	1538	10058	1207	12564	1492	9705	1161
1980-81	16946	1922	11216	1281	16314	1844	10583	1203

SOURCE: Tables A-1 and A-2 and Text in Appendix A.

between the provinces which roughly represents their split in maize acreage. The NIAB expenditures are included in the Punjab expenditures and the Pirsabak expenditures are included in the N.W.F.P. expenditures. Deflating the current maize expenditures into constant 1959-60 Rs. is done in the same manner as before.

Table A-5 presents CIMMYT and Pakistan wheat expenditures. Current CIMMYT expenditures in US dollars are given in column 1. They are obtained from financial statements found in the CIMMYT Review, a yearly publication from the head office in Mexico. Current CIMMYT expenditures are deflated using the USA CPI found in The Economic Report of the President, 1982. Since the money is spent in Mexico and other countries, it is difficult to obtain a deflator. The USA CPI was used because most of the scientific staff are paid in American funds and a good proportion of supplies and equipment originate in the USA. The CIMMYT expenditures are changed into Pakistan rupees using the official 1973 to 1982 exchange rate of Rs. 9.9 to one US dollar.

The CIMMYT expenditures for 1973 to 1981 in columns 1 to 3 are for both maize and wheat research. A breakdown of maize and wheat expenses in the CIMMYT Review, 1982 indicates an almost equal split between the maize and wheat units. Thus, the CIMMYT wheat expenditures as shown in column 4 for the years 1973 to 1981 are one-half that of column 3. Expenditures by CIMMYT and other international agencies such as the Ford and Rockefeller Foundatins prior to 1973 were not available. A generous yearly figure of Rs. 20 million in 1959-60 constant rupees are given to the years 1960-61 to 1971-72.

Table A-5. CIMMYT and Pakistan Wheat Research and Extension Expenditures.

Year	CIMMYT Total Expenditures (Mexico)			CIMMYT and Pakistan Wheat Expenditures		
	Current USA $	Constant 1959-60 USA $	Constant 1959-60 Rupees	CIMMYT Constant 1959-60 Rupees	CIMMYT and Pakistan ‡ E1	CIMMYT and Pakistan ‡ E2
			(In Millions)			
1960-61				20.0	23.9	22.4
1961-62				20.0	25.1	23.6
1962-63				20.0	24.7	22.3
1963-64				20.0	25.6	21.9
1964-65				20.0	26.6	22.3
1965-66				20.0	24.7	22.3
1966-67				20.0	25.0	22.6
1967-68				20.0	24.6	22.4
1968-69				20.0	24.7	22.2
1969-70				20.0	24.8	22.1
1970-71				20.0	26.4	22.9
1971-72				20.0	24.7	22.2
1972-73	8.0	5.3	52.9	26.4	29.8	28.0
1973-74	7.5	4.5	44.4	22.2	25.6	23.9
1974-75	9.1	5.0	49.7	24.8	29.5	27.6
1975-76	11.9	6.2	61.5	30.8	39.1	35.3
1976-77	11.6	5.7	56.3	28.2	36.8	33.3
1977-78	15.2	6.9	68.5	34.2	43.1	40.2
1978-79	17.6	7.2	70.9	35.5	44.2	40.9
1979-80	19.3	6.9	68.5	34.2	47.9	43.3
1980-81	21.8	7.1	70.4	35.2	54.2	45.2

SOURCE: See Text in Appendix A

‡ E1 Includes and E2 Excludes Conventional Extension .

Columns 5 and 6, Table A-5 include the total CIMMYT plus Pakistan wheat research and extension expenditures. Column 5 is the sum of column 4 plus the Pakistan wheat expenditures on research and extension (including conventional extension) from Table A-3. Column 6 is the sum of column 4 plus Pakistan wheat expenditures (excluding conventional extension) from Table A-3.

Appendix B

Productivity Model Data Construction and Sources

The construction and data sources of all the variables used in the estimtion of the productivity models in Chapter 4 are outlined in this appendix. Tables B-1 and B-3 include all the variables used in the productivity models. A matrix of simple correlations of the variables are given in Table B-2. Table B-6 includes the deflators used in the analysis.

The Productivity Index

Two productivity indexes were used and were obtained from Wizarat (1981) and Wizarat (1983). These are presented in columns (1) and (2) of Table B-1. The first productivity index (PI1) is an arithmetic index of productivity constructed by dividing the index of agricultural value added in Pakistan (major and minor crops) by an aggregate agricultural input index. Included in the input index is land, agricultural labor and capital which includes draught animals, private and public tubewells and tractors. The land, labor and capital inputs are aggregated by using factor prices as weights.

The arithmatic index is derived from a linearly homogeneous production function and a discussion along with the derivation can be found in Lu *et al* (1979), USDA (1980) and Yotopaulos and Nugent (1976). The use of the arithmetic index carries with it the assumption of perfect competition and that the inputs are paid there marginal products and that the marginal products are accurately measured by their prices. Also, as pointed out by Domar (1962, p. 601):

> "The marginal products of the inputs are changed only by the 'other forces' and always in the same proportion, so that their ratios remain constant and independent of the ratio of the quantities of the inputs, however fast capital may grow relative to labor."

The second productivity index that was used (PI2) is a geometric index of productivity which was pioneered by Solow (1957) and has come to be known as the Solow index. The index is based on an aggregate production function that exhibits constant returns to scale (usually a Cobb-Douglas but not necessarily) and assumes a perfectly competitive economy and Hicks-neutral technology change meaning that the marginal rates of substitution of inputs remain constant over time. The Solow index combines the changes in inputs using the elasticity of output (factor shares) of each input as weights rather than factor prices as is done by the arithmetic index. The derivation of the Solow index is found in Solow (1957) and Yotopaulos and Nugent (1976).

Apart from the above assumption of the construction of the two productivity indexes, the index may also be biased because of errors in measurement of the data. This is particularly true for the two indexes used in this study and even more true for the earlier yearly indexes. Given the amount of data used in the construction of the two indexes and the various sources, it is not possible to form an opinion of the direction or magnitude of a bias due to data measurement itself. However, it must be said that Pakistani data is among the best of all LDC countries.

The two indexes as shown in Table B-1 move together very closely with a simple correlation coefficient of .99 for the years 1959-60 to 1978-79. They are both similar in magnitude on a year to year basis

Table B-1. Productivity Model Variables.

Year	Productivity Index		Literacy Index	Weather Variable		HYV Introduction		Extension		Research
	Arithmetic (PI1)	Solow (PI2)	(ED)	Total Rain (W1)	Dev. From Mean (W2)	(HYV1)	(HYV2)	(EX1)	(EX2)	(RS1)
	(1959-60 = 100)			(M.M.)				(000'S 1959-60 Rs.)		
1953-54	109.3	108.9								
1954-55	109.9	105.3								
1955-56	106.3	106.1								
1956-57	104.3	104.1								
1957-58	102.3	102.2								
1958-59	104.7	103.7								
1959-60	100.0	100.0	100.0	563.7	215.5			78.2	21.9	49.1
1960-61	89.4	89.7	102.1	375.8	28.2			81.5	24.9	52.9
1961-62	95.5	104.9	104.3	368.2	19.9			88.2	31.8	55.9
1962-63	98.6	98.7	106.4	352.5	4.2			94.5	35.2	59.1
1963-64	101.3	99.9	108.7	256.5	-91.8			103.7	37.5	64.2
1964-65	104.1	103.5	110.9	443.2	94.9			115.8	40.8	71.8
1965-66	101.0	100.3	113.2	273.4	-74.8			121.2	44.1	81.6
1966-67	106.1	105.5	115.6	343.3	-4.9			127.7	48.4	85.4
1967-68	122.1	121.5	117.9	409.1	60.9			131.8	48.8	87.1
1968-69	128.3	128.9	120.5	276.1	-72.1	0.1	0.1	133.8	48.4	90.5
1969-70	144.6	145.3	123.0	260.6	-87.6	1.1	1.0	131.7	46.5	93.1
1970-71	135.7	133.6	125.6	319.2	-29.0	2.3	1.9	130.6	46.1	92.3
1971-72	137.0	137.2	128.2	264.5	-83.8	3.6	2.9	131.2	45.1	93.7
1972-73	136.9	136.8	129.8	258.3	-89.9	4.8	5.4	125.7	38.9	95.1
1973-74	141.5	141.6	131.5	416.5	68.3	4.8	4.8	120.5	37.3	91.8
1974-75	133.9	133.9	133.1	262.8	-85.5	5.6	5.6	111.9	37.3	87.5
1975-76	139.1	139.2	134.8	466.7	118.4	8.3	9.6	105.9	39.2	86.4
1976-77	139.5	139.6	136.4	466.2	117.9	10.0	12.4	108.8	44.7	93.8
1977-78	140.2	140.9	138.2	317.9	-30.3	15.3	15.3	112.5	50.8	100.2
1978-79	144.5	141.8	139.9	412.5	64.2	20.1	28.6	116.2	55.6	106.4

SOURCE: See Text for description and source of data.

Table B-2. Productivity Model Simple Correlation Matrix.

	PI1	PI2	W1	W2	ED	HYV1	HYV2	EX1	EX2	RS1	RSEX1	RSEX2
PI1	1	.99	.96	.06	.99	.65	.61	.99	.98	.99	.99	.99
PI2	.99	1	.96	.06	.99	.64	.59	.99	.98	.99	.99	.99
W1	.96	.96	1	.31	.96	.58	.55	.94	.94	.94	.94	.94
W2	.06	.06	.31	1	.07	.17	.21	.01	.02	.02	.01	.02
ED	.99	.99	.96	.07	1	.64	.59	.99	.93	.99	.99	.99
HYV1	.65	.64	.58	.17	.64	1	.98	.57	.64	.66	.61	.99
HYV2	.61	.59	.55	.21	.59	.98	1	.53	.61	.62	.57	.65
EX1	.99	.99	.94	.01	.99	.57	.53	1	.98	.99	.99	.61
EX2	.98	.98	.94	.02	.98	.64	.61	.98	1	.99	.99	.99
RS1	.99	.99	.94	.02	.99	.66	.62	.99	.99	1	.99	.99
RSEX1	.99	.99	.94	.01	.99	.61	.57	.99	.99	.99	1	.98
RSEX2	.99	.99	.94	.02	.99	.99	.65	.61	.99	.99	.98	1

Using 1959-60 to 1978-79 data from Table B-1.

Table 2-3. Yearly Total Research and Extention Expenditures, Pakistan

Year	Current Research Expenditures	Current Extension Exp.		1959-60 Research Expenditures	1959-60 Extension Exp.	
		Including Conventional Extension	Excluding Conventional Extension		Including Conventional Extension	Excluding Conventional Extension
	(R)	(E1)	(E2)	(R)	(E1)	(E2)
	(000'S Current Rs.)			(000'S 1959-60 Rs.)		
1948-49	3005	8604	574	3742.3	10715.3	714.8
1949-50	3190	3699	584	4121.4	4779.5	754.5
1950-51	3057	3872	558	4001.3	5067.8	730.4
1951-52	3244	3465	537	4064.9	4341.5	672.9
1952-53	3058	3953	542	3572.5	4617.9	633.2
1953-54	3036	4166	568	3414.5	4685.8	638.9
1954-55	3271	4666	560	3807.3	5432.2	651.9
1955-56	3630	4784	703	4259.9	5614.7	825.1
1956-57	6320	6448	3969	6967.6	7109.4	4375.9
1957-58	6739	9142	3998	6848.6	9290.4	4063.0
1958-59	7589	11946	4467	8000.6	12627.9	4721.9
1959-60	7973	14606	3878	7972.9	14605.7	3878.0
1960-61	7310	8427	3918	6992.9	8077.8	3729.5
1961-62	8767	14455	9328	7276.7	11808.5	7568.2
1962-63	11031	13607	5279	8697.9	10678.0	4117.9
1963-64	14479	18123	3865	11003.6	13801.1	2951.2
1964-65	17969	21588	5046	13618.8	16782.1	3975.9
1965-66	11321	14982	5193	8069.1	10807.1	3868.9
1966-67	12874	17753	7244	8644.8	12140.0	5180.9
1967-68	16086	17341	7028	10240.3	11182.4	4759.0
1968-69	16718	17548	5247	10553.6	11240.4	3607.9
1969-70	10412	16280	4000	7236.0	10546.9	2927.2
1970-71	13493	20239	4486	8418.8	13533.8	3486.4
1971-72	15265	16232	3672	8590.1	8692.9	2628.4
1972-73	17333	18360	3796	5464.9	6336.9	1413.6
1973-74	38036	35186	11528	6704.4	5407.9	2459.5
1974-75	77953	46631	15456	12463.9	5289.9	3038.5
1975-76	97001	93762	28608	15460.5	10794.6	5786.2
1976-77	99783	116461	52784	15085.3	13652.1	9499.6
1977-78	123662	133768	72190	16472.6	15790.3	11153.5
1978-79	146817	138899	64375	18523.8	14891.3	9623.1
1979-80	168573	242952	130588	20039.8	26052.9	18022.9

and follow similar turning ponts with the exception of 1962-63. The two indexes are constructed using exactly the same data and although there may be methodological reasons for choosing one index over the other, there is little reason to here because of their similarity. A discussion on the issues of productivity and productivity indexes can be found in Domar (1962) and Lave (1966).

Weather Variable

The weather variable consists of a measurement of yearly rainfall in millimeters. Two different variables were constructed (1) total yearly rainfall in millimeters (W1) and (2) the deviation from the mean of total yearly rainfall in millimeters (W2). Monthly rainfall figures are given by district from the Regional Meteorological Centres in Lahore and Karachi. The average rainfall per year for all Pakistan was obtained by taking the simple average of all the districts by month and then summing the monthly figures to obtain the total. All the monthly rainfall data by district was obtained from the Ministry of Food and Agriculture, Planning unit, Islamabad.

Education

The education variable (ED) consists of an index (1959-60 = 100) of a linear interpolation of the literacy rates of rural males (ages 20-24) from the 1961 Census (25.3%), the 1971-72 Census (31.3%) and the 1980-81 Census (preliminary 34.8%). Literacy is defined by the 1961 Census as "the ability to read with understanding a short statement on everyday life in any language." The spirit of the 1961 definition corresponds to the definitions of the 1971-72 and 1980-81

Censuses and are therefore comparable. It is however not possible to extrapolate the index to any great extent previous to the 1961 Census because the 1951 Census literacy figures are not comparable. The 1951 definition of literacy is "a person who declared ability to read any language" which does not include the "understanding" portion that the three latest censuses require. To be more specific, one was considered literate in the 1951 Census if one had the ability to cite a memorized passage of the Koran even if there was no understanding and ability to read any language.

HYV Introduction Variable

The HYV introduction variable is a variable that attempts to measure the influence upon productivity from those HYV's that are being used by Pakistani farmers but that have been introduced from another country. This means that the HYV was produced by a research system from another country or international center. Two variables have been constructed. The first (HYV1) is the simple addition of hectares sown to wheat and rice HYV's that are introductions and expressed as a percentage of total hectares cropped. The percentage of hectares of wheat in this category is obtained from Tables in Appendix C. The percentage of rice in this category is considered to be all IRRI rice hectares and is obtained from Agriculture Statistics of Pakistan (various years).

The second variable (HYV2) is a weighted average of the wheat and rice hectares from above by their procurement prices (Basic Facts, 1981, p. 46).

Research and Extension Expenditures

The yearly research expenditures for R_t and the yearly extension expenditures $E1_t$ and $E2_t$ are included in Table B-3. Research expenditures represent monies spent incountry by both Pakistani and donor agencies. Extension expenditures E1 include expenditures on conventional field assistance type extension, seed multiplication and distribution expenditures and extension related activities by PARC and donor agencies. Extension expenditures E2 are expenditures E1 excluding the expenditures on conventional field assistance extension.

Compiling research and extension expenditures was a difficult and time consuming task. No agency in Pakistan is charged with the responsibility of establishing a yearly total of research and extension expenditures. The funds for research and extension come primarily from four sources; 1) the Federal and Provincial governments, 2) Cess (levy) on agricultural exports, 3) PARC, and 4) donor agencies of which USAID funds the largest share.

1) The Provincial and Federal governments

The expenditures by provincial and Federal governments are obtained from several sources. The combined development and non-development expenditures for the years 1948-49 to 1955-56 come from yearly Provincial budget publications entitled "Detailed Estimates of Revenues and Expenditures". Non-development expenditures are expenditures on on-going projects. Development expenditures are expenditures on new projects, the majority of which will appear on the non-development ledger after the initial development stage is over.

The proportion of development expenses for capital items is usually higher than capital expenses in the non-development category.

The non-development expenditures for the years 1956-57 to 1968-69 are found in the yearly West Pakistan Budget publication called "Details of Demands for Grants and Charged Expenditures, Government of West Pakistan". The budget is no longer by Province but amalgamated into a West Pakistan Budget. All the expenditures are actual expenditures with the exception of 1968-69 which are revised budget figures.

The non-development expenditures for 1969-70 to 1979-80 are obtained from yearly Provincial publications entitled "Estimates of Charged Expenditures and Demand for Grants". The figures are revised estimates and not actual estimates. The procedure is to first allocate funds, then complete a revised estimate in the middle of the year and then a final or actual estimate after the year is closed out. Actual estimates have not been reported after 1967-68 with a few exceptions and thus only revised estimates are available. An attempt to obtain actual estimates from the Finance Secretariate proved fruitless. Conversations with budget personnel lead me to believe that on balance, revised estimates of research expenditures are higher than what the actuals would be. This however, seems not to be a large problem with extension expenditures. Also, expenditure figures for 1969-70 are only available for the Sind thus other provincial expenditures for 1969-70 are assumed to take on the same increase over the 1968-69 year as did the Sind expenditures.

The research expenditures include several categories as follows; Direction, Superintendence, Experimental Farms, Seed Farms, District Farms and an Agricultural Experiment and Research category. Each of the categories are divided into 1) pay and other (salaries) which includes pay of officers, pay of establishment, travel and other (housing allowance) and 2) contingencies (capital) which include purchase of capital items. The categories included in extension expenditures are; Direction, Superintendence, Experimental Farms, Seed Farms, District Farms, Demonstration and Propaganda and Extension Services. Each category is also broken down into 1) salaries and 2) capital. The proportion of expenditure assigned to research and to extension for the categories of Direction, Superintendence, Experimental Farms, Seed Farms and District Farms are made on the basis of figures from the Punjab, 1974-75 to 1979-80. Previous to 1974-75, the Punjab as well as the other provinces for the years 1948-49 to 1979-80 did not break down the expenditures.

The development expenditures for the period 1956-57 to 1979-80 come from various sources. A lump sum figure for the years 1956-57 to 1959-60 was obtained for West Pakistan from Mr. M. Hussain, Planning Secretariate, Planning commission, GOP, Islamabad. Yearly figures for West Pakistan for the years 1960-61 to 1969-70 were obtained from the second and third evaluations of the five year plans for 1960-65 to 1965-70 also from the Planning Commission, GOP. Research expenditures come under the category of "Agriculture Research on Crop Production". Extension includes the categories "Agricultural Extension" and "Seed Multiplication and Distribution". Yearly development

figures by province and for the central Government are available for the same categories for the years 1970-71 to 1979-80. These figures however are mainly allocated and revised estimate figures. These figures are obtained from the publication, Evaluation of the First Two Years of the Fourth Five Year Plan 1970-75, Planning Commission, GOP, April 1973 and various issues of the Annual Plan, Planning Commission, GOP, Islamabad. The development figures for 1955-56 to 1979-80 are not divided into pay and other (salaries) and contingencies (capital) and an overall 40-60% split is used respectively and is based on conversations with the Planning Commission.

Yearly GOP non-development expenditures for research and extension are from Demands for Grants and Appropriations, GOP, 1952-53 to 1979-80.

All the individual yearly data that was collected from the budget books have been typed into tables and is available from the member, Social Science, PARC, Islamabad. All the budget books can be found by going to both the Planning Secretariate Library, Islamabad and the State Bank Library, Karachi.

The yearly current expenditures for research and extension by the two categories of salaries and capital are presented in Table B-4. The research expenditures are corrected by decreasing the non-development expenditures by 20 percent for the years 1969-70 to 1979-80 to reflect that they are not actual but revised figures. The research data for the years 1970-71 and 1971-72 have also been revised further downward because the development figures for this period are

Table B-4. Research and Extension Expenditures By Source In Thousands of Current Rs.

Year	Provincial and Federal Expenditures				COTTON CESS	PARC	USAID/FORD PL-480	Pirsabak	
	Research		Extension ♦						
	Salaries	Capital	Salaries	Capital				Services	Equip.
	(000's Current Rs.)								
1948-49	1312.1	860.0	1272.2	7332.2	833				
1949-50	1353.2	1003.8	1266.2	2433.1	833				
1950-51	1470.4	753.6	1635.0	2336.7	833				
1951-52	1583.2	827.6	1630.1	1834.4	833				
1952-53	1384.4	840.7	1994.9	1958.0	833				
1953-54	1591.2	611.3	2159.4	2006.3	833				
1954-55	1644.1	793.4	2845.8	1820.5	833				
1955-56	1920.3	876.2	3637.2	1146.5	833				
1956-57	3385.7	2100.9	3510.7	2937.5	633				
1957-58	3371.9	2347.1	4602.3	4539.5	1020				
1958-59	3756.9	2289.7	6096.7	5849.3	1522				
1959-60	4163.1	2466.9	6984.9	7620.8	1343				
1960-61	3129.1	2028.4	4728.2	3699.2	2152				
1961-62	5609.2	1297.2	7100.9	7353.6	1861				
1962-63	5439.1	3896.4	6505.0	7101.6	1696				
1963-64	7185.5	5272.5	8670.9	9452.0	2021				
1964-65	9565.8	6220.8	9917.3	11670.8	2182				
1965-66	5700.4	3588.1	7722.4	7259.6	2033				
1966-67	6718.9	3708.6	9380.4	8372.9	2447				
1967-68	7774.6	4221.5	9141.3	8200.0	4090				
1968-69	8131.9	4129.6	9460.0	8088.3	4456				
1969-70	3634.6	2314.7	9392.0	6888.0	4463				
1970-71	5918.6	3567.9	11548.6	8624.8	3940		66		
1971-72	6760.7	3956.8	10661.3	5060.9	4037		510		
1972-73	6306.4	3960.1	10939.8	6710.0	6356		710		
1973-74	15909.1	8708.2	15632.7	10903.5	7319	2702	3335	63.2	
1974-75	31172.9	16957.2	16644.0	11779.4	8567	14528	6381	344.6	
1975-76	34997.5	16470.7	31510.4	27265.0	8639	28466	8288	31.4	108.4
1976-77	42472.4	23468.6	34788.6	43793.5	6120	17435	8862	290.0	835.0
1977-78	55463.2	27532.7	50629.9	55156.6	5249	20112	13620	372.6	1312.2
1978-79	66232.9	24252.2	49813.7	54663.0	8267	21491	15884	554.8	135.0
1979-80	70248.1	35470.3	88349.7	106392.7	11184	31849	19345	383.4	93.0

SOURCE: See Text of Appendix B for description and source of data.

♦ Extension includes conventional Extention expenditures.

allocation and not actual figures. Conversations with the Planning Commission suggest that less than 50 percent of the allocated expenditures were spent. (This is the period of the Bangladesh war.)

2) Cotton Cess

The second place from which funds for research are obtained are from a Cess or levy on agricultural exports. For the most part, Cess funds have already been included in the research expenditures by Provincial and Central Governments and by PARC. However, the cotton Cess administered by the Pakistan Central Cotton Committee (PCCC) in Karachi is not included and the figures are found in Table B-4. These expenditures have been obtained from the PCCC in Karachi.

3) PARC

The PARC budget is shown in Table B-4. Its source is Annexure-XIII, Review of Agricultural Research System in Pakistan, A. Wahid, PARC, 1982. The expenditures in Annexure-XIII are allocation figures and not actuals. Based on the difference between the actual and revised figures for 1980-81 and 1981-82 obtained from PARC (the only available actuals), the expenditures in Annexure-XIII are corrected using this information. Thus the PARC figures in Table B-3 include 75% of non-development plus 50% of development plus 50% of Cess fund expenditure figures as shown in Annexure-XIII.

4) Donor Agencies

The expenditures under the title USAID/FORD/PL-480 are from two sources. First, the USAID expenditures were obtained from the USAID Mission to Pakistan, Islamabad and includes expenditures under

391-0296 for FY 1969 to 1981. The FORD and PL-480 expenditures are 50 percent of the figures found in Annexure-XIII cited above.

The expenditures for expert services and equipment donated by the Australians for work on the Pirsabak research station in N.W.F.P. is also included in Table B-4. These figures were obtained from T. Blythe, Australian Aid, Australian Embassy, Islamabad.

The final yearly research expenditures (R) in thousands of 1959-60 RS, as shown in Table B-3 are computed from Tables B-4 and B-5 as follows. Provincial and Federal government salaries are deflated by the agricultural wages deflator (D2) and the Capital (contingencies) are deflated by the capital goods import index (D1). (See this Appendix for details on the deflators.) Seventy percent of the Cotton Cess expenditures are deflated by D2 and 30 percent by D1. Only 70 percent of the Cotton Cess expenditures from 1969-70 to 1979-80 are considered as crop research expenditures. The other 30 percent is spent on technical research in the processing area and on marketing and economic research. This type of research has been carried out by the PCCC since its inception however, the technical research has become more pronounced since 1969-70.

Seventy percent of PARC expenditures are deflated by D2 and 30 percent by D1. Of the total PARC expenditure, 90 percent is considered crop research expenditure. The USAID/FORD/PL-480 expenditures are deflated by D1 and 80 percent of the total expenditure is considered for crop research purposes. The Pirsabak expenditures for services and equipment are both deflated by D1 with 50 percent of the

Table B-5. Research and Extension Expenditures By Source In Thousands of 1959-60 Rs.

Year	Provincial and Federal Expenditures				Cotton CESS	PARC	USAID/FORD PL-480	Pirsabak	
	Research		Extension ♦						
	Salaries	Capital	Salaries	Capital				Services	Equip.
	(000's 1959-60 Rs.)								
1948-49	1633.9	1070.9	1584.3	9131.0	1037.4				
1949-50	1748.3	1296.9	1635.9	3143.5	1076.2				
1950-51	1924.6	986.4	2009.2	3058.5	1090.3				
1951-52	1983.9	1037.1	2042.7	2298.7	1043.9				
1952-53	1617.3	982.1	2330.5	2287.4	973.1				
1953-54	1789.9	687.6	2429.0	2256.8	937.0				
1954-55	1913.9	923.6	3312.9	2119.3	969.7				
1955-56	2253.9	1028.4	4269.0	1345.7	977.7				
1956-57	3732.9	2316.3	3870.7	3238.7	918.4				
1957-58	3426.7	2385.3	4677.1	4613.3	1036.6				
1958-59	3971.4	2420.4	6444.7	6183.2	1608.9				
1959-60	4162.0	2466.9	6984.9	7620.8	1343.0				
1960-61	3055.8	1897.5	4617.4	3460.4	2039.6				
1961-62	4757.6	1020.6	6022.8	5785.7	1498.5				
1962-63	4440.1	2945.1	5310.2	5367.8	1312.7				
1963-64	5374.3	4080.9	6485.3	7315.8	1548.4				
1964-65	6516.2	5344.4	6755.7	10026.5	1758.1				
1965-66	3545.0	2967.7	4802.5	6004.6	1556.4				
1966-67	3819.7	3015.1	5332.8	6807.2	1809.9				
1967-68	4078.9	3287.8	4796.1	6386.3	2873.5				
1968-69	3939.9	3398.8	4593.3	6657.0	3214.9				
1969-70	1624.8	2133.4	4198.5	6348.4	3477.9				
1970-71	2441.7	3622.3	4764.3	8756.1	2301.3		53.6		
1971-72	2573.5	3551.9	4058.4	4542.9	2098.4		366.2		
1972-73	2216.7	1440.0	3845.3	2440.0	1601.7		206.5		
1973-74	3208.8	1584.7	3153.0	1984.3	962.7	456.9	485.5	5.8	
1974-75	5446.0	2868.1	2907.8	1992.1	1024.2	2233.2	863.3	29.1	
1975-76	5390.9	3126.6	4853.7	5175.6	1083.5	4588.1	1258.6	2.9	10.3
1976-77	6405.1	4046.3	5246.4	7550.6	710.9	2603.7	1222.3	25.0	71.9
1977-78	7084.3	4320.2	6466.9	8654.7	544.4	2681.8	1709.7	29.2	102.9
1978-79	7839.1	5168.6	5895.8	8248.5	816.7	2729.8	1917.5	41.9	10.2
1979-80	7704.3	5147.3	9689.6	15439.4	1052.8	3854.9	2245.8	27.8	6.7

SOURCE: See Text of Appendix B for description and source of data.

♦ Extension includes conventional Extention expenditures.

total expenditure considered to be research oriented.

The final yearly research expenditures E1 and E2 in thousands of 1959-60 Rs. as shown in Table B-4 are constructed from Tables B-4 and B-5. Salaries and capital expenditures for both E1 and E2 are deflated by D2 and D1 respectively. (The salaries and capital expenditures shown in Tables B-4 and B-5 are total expenditures associated with E1.) Of the total expenditures from the remaining source of funds for extension in Tables B-4 and B-5, 10 percent of PARC, 20 percent of USAID/FORD/PL-480 and 50 percent of all Pirsabak expenditures are considered extension. These expenditures have been deflated in the same manner as the research expenditures.

From Table B-3 come the research and extension stock variables given in Table B-1 which are constructed as follows:

1) $RS1_t = \sum_{i=1}^{10} R_{t-i}$

2) $EX1_t = \sum_{i=0}^{10} E1_{t-i}$

3) $EX2_t = \sum_{i=0}^{10} E2_{t-i}$

The combined research and extension stock variables are given by:

1) $RSEX1_t = RS1_t + EX1_t$ (includes conventional extension)

2) $RSEX2_t = RS1_t + EX2_t$ (excludes conventional extension)

The construction of the stock variables assumes a one-horse shay depreciation pattern of scientific knowledge generated by the human

capital embodied in researchers and the physical capital that they work with. The decision to sum over 10 years for the research stock variables and 11 years for the extension variables is admittedly based on available data. It is somewhat pleasing however to find that the research and extension stock variables over time closely track the productivity indexes and are so highly correlated.

With respect to the physical capital stock, it may be reasonable to assume a 10 or 11 year average life span. Although buildings produce services for longer periods, they do require maintenance; however equipment and vehicles used in the research and extension system rarely get to be 10 years old before they are scrapped.

The combined research and extension figures used for the distributed lag variables are given by:

1) $RE1_t = R_t + E1_t$ (includes conventional Extension)

2) $RE2_t = R_t + E2_t$ (excludes contentional Extension)

Research and Extension Expenditure Deflators

Two deflators were used to change current year research and extension expenditures into 1959-60 constant Rs. The first is a capital goods imports deflator (D1) and the second is an index of the wages in agriculture (D2). The Consumer Price Index (CPI) was not used because it was felt that it did not represent the inflation rates within the research and extension system for the latter years. The indexes, 1959-60 = 100 are shown in Table B-6.

The deflators D1 and D2 are those used in the PIDE Macro-Econometric model of Pakistan Economy (Naqvi et al, p. 194 and p. 198).

Table B-6. Research and Extension Expenditure Deflators.

Year	Capital Goods Imports (D1)	Wages In Agriculture (D2)	Consumer Price Index (CPI)
	(1959-60 = 100)		
1948-49			80.3
1949-50			77.4
1950-51			76.4
1951-52			79.8
1952-53			85.6
1953-54			88.9
1954-55			85.9
1955-56			85.2
1956-57			90.7
1957-58			98.4
1958-59			94.6
1959-60	100.0	100.0	100.0
1960-61	106.9	102.4	101.8
1961-62	127.1	117.9	104.6
1962-63	132.3	122.5	103.2
1963-64	129.2	133.7	106.5
1964-65	116.4	146.8	112.9
1965-66	120.9	160.8	118.6
1966-67	123.0	175.9	129.1
1967-68	128.4	190.6	132.0
1968-69	121.5	206.4	134.0
1969-70	108.5	223.7	140.0
1970-71	98.5	242.4	147.1
1971-72	111.4	262.7	155.7
1972-73	275.0	284.5	170.0
1973-74	549.5	495.8	221.7
1974-75	591.3	572.4	281.4
1975-76	526.8	649.2	313.2
1976-77	580.0	663.1	341.8
1977-78	637.3	782.9	364.4
1978-79	662.7	844.9	393.8
1979-80	689.1*	911.8*	433.6
1980-81	716.6*	983.9*	493.3

SOURCE: See Text of Appendix B for description and source of Deflators.

* Estimate

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They are only available for the years 1959-60 to 1978-79. For the years previous to 1959-60, the CPI index is used.

The capital imports index D1 was used to deflate capital purchases because much of the capital purchases such as laboratory equipment, tractors and implements and transportation vehicles which make up the bulk of capital purchases are imported. The capital imports index also reflects the Pakistani exchange rate policy better than that of the CPI. Up to July 31st, 1955, 1 US $ = Rs 3.31. From August 1st, 1955 to May 11th, 1972, 1 US $ = Rs 4.76. From May 12th, 1972 to February 15th, 1973, 1 US $ = Rs 11.00. From February 16th, 1973 to January, 1982, 1 US $ = Rs 9.90 (Pakistan Economic Survey, 1981-82, p. 186).

An index of agricultural wages D2 was used to deflate salaries and employee allowances which include a housing and travel allowance. The CPI was not used because it would not reflect the upward spirals in research salaries in the latter years. Conversations with Research Station Directors alluded to the fact that although yearly budgets increased, more and more of the total increase went to salaries and not for capital purchases. This presented a concerted effort on the part of the research system to attract and keep trained personnel.

The CPI index is included in Table B-6 as a comparison. The 1948-49 to 1970-71 figures are the general consumer's price index for industrial workers in Karachi (25 years of Pakistan Statistics, p. 347). The 1970-71 to 1980-81 CPI are the general consumer's price index for all groups in Pakistan (Pakistan Basic Facts. p. 123).

APPENDIX C

Estimation of the Wheat and Maize Yield Advantage and the Shift Parameter

The index number approach using the horizontal supply shift method requires knowledge of what the production of a certain commodity would have been given that producers did not have access to the innovation under study. The most popular way of specifying the shift from S_0 to S_1 in Figure 3.1, Chapter 3, follows that of the Ayer-Schuh and Akino-Hayami models as indicated below:

$$(1) \qquad k_\tau = \sum_{i=1}^{n} \left[(1 - Y/Y_i) \cdot L_{i\tau} \right] \times 100$$

where:

k_τ = the percentage decrease in production that would have resulted if producers used the old unimproved varieties;

Y = the average yield of the unimproved varieties that would be grown in the absence of new improved varieties (the base yield);

Y_i = the yield of an improved variety i that is sown in year t;

$L_{i\tau}$ = the proportion of total land sown that is sown to variety i in year t;

n = the number of improved varieties sown in year t; and

Y/Y_i = the inverse of the yield advantage of improved variety i.

A problem arises in obtaining an accurate measure of the yield advantage Y_i/Y. In some studies, Y_i and Y are arrived at through the

use of experimental station yield trial data since this is a readily available and most often the only reliable source. It is also the only source of data that can show the relative yields by variety over the history of the crop development research.

One of the arguments against using experimental yield trial data is that superior management practices and techniques are used and therefore the results may not reflect the on-farm situation. Another argument is summed up by Hertford, Ardila, Rocha and Trujillo (1977, page 87):

> ".....estimates based only on comparisons of yields obtained on plots seeded to new varieties and others seeded to unimproved varieties would be biased upward because of the strong, positive interactions of the new varieties with such inputs as fertilizers and water."

The argument by Hertford et al is that the yield advantage estimate would be biased upward because the estimate may also include the contribution made by inputs such as fertilizers and water. To account for this problem, they estimated the yield advantages of new varieties in Columbia by estimating production functions of yield as a function of new varieties and other inputs. For example, using data from commercial rice trial plots, they estimated yield as a function of 20 variables which included size of plot, seeding rate, seven seed variety variables, two time variables and four variables to differentiate locations. In comparing k obtained using the formula as presented in equation (1) and the k obtained from the regression results for rice, the former was an average twice that of the latter.[1/]

[1/] For an alternate procedure for estimating k, see G. M. Scobie and Rafael Posada T. (1977).

The use of experimental yield trial data does not provide a good estimate of the shift parameter k in less developed countries (LDC's) because of the previous arguments. However, in the case of some crops in developed countries (DC's) experimental yield trial data may offer a good estimate of the yield advantage and shift parameter k. Take for example, the case of rapeseed breeding in Canada (Nagy and Furtan, 1978). Rapeseed is a specialized crop grown by above average farmers who in general apply optimal amounts of fertilizers and other inputs. Furthermore the old base yield varieties are similar in response to inputs like fertilizer.

The rapeseed experimental yield data gives a close estimate of a change in yield solely due to varietal improvement because the experimental yield data for each new variety is averaged over several repetitions at many geographical locations within the crop growing area and over several years under profit maximizing input use (not output maximizing) and management. The base yield varieties were included in the yearly experiments, thus the yield of the base varieties Y are compared with the yields of new varieties Y_i under modern cultural practices. Also, due to the method of calculating k, the experimental yield varietal difference is transmitted as a percentage and not in absolute terms. For example, if experimental yield trial data indicates that a new variety exhibits a four bushel per acre increase over the base yield Y of 40bushels per acre, then k = 9.09%. If the on-farm yield was 35 bushels per acre, then the pre-innovation yield would be (35 - (.0909 x 35)) = 31.82 bushels per acre and not (35 - 4) = 31 if the absolute value were used. It is also the opinion of the

rapeseed breeders that the relative yield increases from experimental trials can be expected to be transmitted to on-farm yields under average farm conditions and where farm management ability and practices are of good standards. Thus for crops grown in DC's such as rapeseed, experimental yield trial data may give good estimates of the yield advantage of new varieties.

The Use of On-Farm Yield Constraints Data in Estimating the Yield Advantage

The estimation of the yield advantage using the Hertford, et al, method does require substantial data which is not readily available in most LDC countries. A new source of data may exist for the estimation of the yield advantage due to varietal yield increasing research. The source of data is from the "On-Farm Yield Constraints Studies" that are now being conducted in several LDC's.

The main focus of the On-Farm Yield Constraint studies are to measure the on-farm yield gap between existing recommended practices and existing farm practices. The analysis shows the contribution to output of individual test factors that make up the gap between existing farm practices and recommended practices. Factors such as the level of fertilizer use, weeding, planting time period and planting depth have been analyzed (deDatta, et al).

Several on-farm yield constraint trials have also included variety as one of the test factors. Furthermore, some of the trials have used pre-HYV's versus post-HYV's as the test factors. The information gained from such trials can be used in determining the yield advantage of HYV's. Table C-1 and Table C-2 show the results of wheat yield

Table C-1 Wheat Yield Constraint Trial Data on Rainfed Land, Pakistan.

Treatments	Yield Index
1. V1F1W1	100.0
2. V1F5W1	128.2
3. V1F1W5	107.1
4. V1F5W5	136.5
5. V5F1W1	116.1
6. V5F5W1	148.0
7. V5F1W5	128.3
8. V5F5W5	155.7

Six locations, three replications (Punjab and NWFP locations).

V1 = Farmers Variety (C-591)

F1 = Farmers Fertilizer (50N and 26P lbs/acre)

W1 = Farmers Weeding (no practice)

V5 = Recommended Variety (Lyallpur - 73)

F5 = Recommended Fertilizer (101N and 75P lbs/acre)

W5 = Recommended Weeding Practice (two weedings)

Source: M. Manzoor Ali, On-Farm Yield Constraints Research In Pakistan; Pakistan Agricultural Research Council, Islamabad.

Table C-2 Wheat Yield Constraint Trial Data on Irrigated Land, Pakistan.

Treatments	Yield Index
1. V1F1W1	100.0
2. V1F5W1	108.9
3. V1F1W5	110.7
4. V1F5W5	101.8
5. V5F1W1	155.3
6. V5F5W1	164.3
7. V5F1W5	150.0
8. V5F5W5	167.8

four replications (Sind locations).

V1 = Farmers Variety (mainly C-591 and other tall varieties)

F1 = Farmers Fertilizer (50N and 20P lbs/acre)

W1 = Farmers Weeding (no practice)

V5 = Recommended Variety (ZA-77)

F5 = Recommended Fertilizer (120N and 60P lbs/acre)

W5 = Recommended Weeding Practice (one hand weeding)

Source: Natali, A. H., Annual Progress Report, 1980-81, Wheat Section, Agricultural Research Institute, Tandojam, Pakistan.

Table C-3 Wheat Yield Advantages from Varietal Improvement Research.

Input Category	Treatments	Unirrigated Yield Index	Unirrigated Yield Advantage	Irrigated Yield Index	Irrigated Yield Advantage
I	V1F1W1	100.0	1.161	100.0	1.553
	V5F1W1	116.1		155.3	
II	V1F5W1	128.2	1.154	108.9	1.509
	V5F5W1	148.(		164.3	
III	V1F1W5	107.1	1.198	110.7	1.356
	V5F1W5	128.1		150.0	
IV	V1F5W5	136.5	1.141	101.8[1/]	1.648
	V5F5W5	155.7		167.8	

Source: Tables 1 and 2.

Treatment V1F5W5 under irrigated conditions would appear to be lower than expected thus biasing the yield advantage of input category IV upward.

constraint trials in Pakistan on Barani (rainfed) and irrigated land respectively. Three test factors are involved in the trials:
1) farmers variety (tall variety) versus recommended HYV variety;
2) farmer fertilizer application rate versus recommended rates; and
3) farmers weeding practice versus recommended. All other inputs are held constant at a level of good farm practices and input use. The trials were conducted on farmers fields.

The information contained in Tables C-1 and C-2 can be used in calculating the wheat yield advantage of HYV's in Pakistan. By rearranging th treatments as is done in Table C-3, the contribution to yield from the use of HYV's under four different input levels can be established. For example, category I in Table C-3 holds constant the two test factors of fertilizer and weeding at the farmers input levels of F1 and W1 while allowing the variety test factor to change from the farmers variety V1 to the recommended HYV V5. The yield advantage of using the HYV holding the other test factors at F1W1 can then be calculated and is 16.1 percent or 1.161 and 55.3 percent or 1.553 for unirrigated and irrigated land respectively.

As noted in Table C-3, information of the yield advantage by variety is not available and therefore equation (1) must be modified. To calculate the yield advantage of wheat, the old tall variety C-591 and the two HYV's LYP-73 and ZA-77 will become proxies for the base yield (Y) and all HYV's (Y_i) in equation (1) respectively. The C-591 variety was one of the most popular pre-semi-dwarf varieties grown in Pakistan and its average yield and characteristics are very similar to other tall varieties. The average yield and characteristics of LYP-73

and ZA-77 on average are also very similar to other semi-dwarf varieties grown in Pakistan. Secondly, instead of weighting each variety's yield advantage by the proportion of land it was sown to in year t, an overall yield advantage figure would be obtained by weighting the yield advantage of each of the four input categories in Table C-3 by the proportion of land sown to HYV's in each category. However, in the case of Pakistan, accurate figures of the land sown to each input category of Table C-3 are not available. When equally weighted, the yield advantage would be 1.164 and 1.517 for unirrigated and irrigated land respectively. However, in Pakistan, most of the total production from the area sown to HYV's of wheat would come from input categories I and III. Equal weighting of categories I and III would give a yield advantage estimate of 1.180 and 1.455 for unirrigated and irrigated land respectively.

The yield advantage for irrigated and unirrigated land can then be weighted by the area of unirrigated land sown to HYV's and the area of irrigated land sown to HYV's to produce the overall yield advantage due to the varietal improvement of wheat. About 10 percent of all HYV's sown in Pakistan are sown on unirrigated land, thus, the overall yield advantage is 1.43.

In comparison to the 1.43 wheat yield advantage figure derived from yield constraints data, Sidhu's production function analysis indicates yield advantage figures ranging from 1.23 to 1.45 for wheat in the Indian Punjab in 1967-68 and Columbian research analysis in 1971 suggested a 1.46 figure for semi-dwarf wheat varieties

(Dalyrymple, 1977). A yield advantage figure of 1.40 will be used in the study.

A comparison of the wheat yield advantage using the On-Farm Yield Constraints data can be made with the Yield advantage calculated from experimental yield trial data from Pakistan. The average experimental research station yield in kg/acre of the dominant pre-HYV wheat varieties of C228, C217, C591, C518, C271 and C273 is 890.6. The average experimental research station yield in kg/ha of the dominant HYV's of MexiPak Ch-70, Blue Silver, SA-42, Yecora and Pari-73 is 1697.2/ The simple calculation of the yield advantage using experimental research station data (1697.5 ÷ 890.6) is 1.91 which is more than twice the yield advantage of the 1.43 calculated using On-Farm Yield Constraints data.

Another check is to make sure that the 1.40 yield advantage does not claim 100% or more of the actual farm yield increase but leaves a portion of the farm level yield increase to other inputs such as increased fertilizer and irrigation. A quick check is to compare the most recent farm yields with farm yields in the period prior to the adoption of HYV's. The ratio of the five year average farm level yields of 1976-77 to 1980-81 and 1960-61 to 1964-65 is 1491 kg/ha 824 kg/ha = 1.81 (Pakistan Basic Facts, 1980-81, Table 4.5). The 1.81 figure leaves sufficient space for the contribution of other inputs. Furthermore, the 1.81 figure is biased downward because the five year

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2/Experimental yield trial data from Dr. M. A. Bajwa. Director. Wheat Research Institute, Faisalabad, Pakistan.

average 1976-77 to 1980-81 figure is derived from total Pakistan yearly averages that include yields from the 20% of the total area sown to tall varieties.

A similar procedure can be used to calculate the yield advantage from crop development reserch for maize. Table C-4 indicates the yield advantage for maize in the Punjab and N.W.F.P. which are the two major maize producing provinces in Pakistan. The source of maize data in Table C-4 does not allow a breakdown into more than two categories. However, the maize data is pooled over seveal years and over more locations than for wheat.

In the estimation of the overall Pakistan maize supply shifter, a 1.16 and a weighted 1.16 + 1.24 = 1.22 yield advantage is used.3/ For the estimation of the provincial maize yield advantage figures, 1.16 is used for the N.W.F.P. and both a 1.16 and a 1.24 figure is used alternatively for the Punjab. Unfortunately, no other source of maize yield advantage figures are available for comparison; however Izumo (1976, p. 7) states that "recommended varieties of maize yield 20-25% more than unimproved varieties when both are grown under traditional cultural practices." In checking the farm level yields as was done for wheat for the same five year averages, the ratio if 1244 kg/ha ÷ 1027 kg/ha = 1.22 (Pakistan Basic Facts, 1980-81, Table 4.5). The 1.22 figure is similar to the overall Pakistan maize yield advantage of 1.22. However, the 1.22 farm level yield ratio is substantially

3/The weighted yield advantage figure of 1.22 is obtained by weighting the 1.16 and 1.24 YA figures by the percentage HYV hectares sown to N.W.F.P. and the Punjap respective as give in Table C-12.

Table C-4 Maize Yield Advantages from Varietal Improvement

Input Category	Treatments[1/]	Punjab Yield Index[2/]	Punjab Yield Advantage	NWFP Yield Index[3/]	NWFP Yield Advantage
I	V1P1	100.0	1.237	100.0	1.157
	V5P1	123.7		115.7	
II	V1P5	135.2	1.236	135.5	1.190
	V5P5	167.2		161.3	

Source: Progress Report, Cooperative Research Program, Maize, Millets and Sorghum, 1975-1981. Pakistan Agricultural Research Council, Islamabad, 1981 and The Tenth Inter-Asian Corn Improvement Workshop, Agricultural Research Council, Islamabad, 1975.

1/ V1 = Unimproved Farmers Variety
V5 = Recommended Varieties for each Province
P1 = Farmers Practices
P5 = Recommended Practices (line sowing, appropriate plant population, 66N and 33P kg/ha and plant protection insecticide).

2/ Two years of data, 84 locations in first year and 6 locations in second year.

3/ Four years of data; 458 locations in first year, 326 locations in second year, 285 locations in the third year, locations not available for fourth year.

biased downward because the 1976-77 to 1980-81 Pakistan overall yearly average yield data includes yields from the 50% of those hectares sown to lower yielding non-HYV maize.

Estimation of the Shift Parameter

The Shift Parameter for Wheat

The shift parameter k for wheat is found yearly using the following forumla:

$$k_T = 1 - \frac{1}{((\cancel{1 - YA})\ YA - 1) \times LHYV_T) + 1} \qquad (2)$$

where:

k_T = the percentage decrease in production that would have resulted if producers used the old tall wheat varieties in year t;

$LHYV_T$ = the proportion of land sown to HYV's in year t; and

YA = the yield advantage of the crop in question as described in the previous section.

An estimation of the shift parameter for Pakistan HYV wheat is given in Table C-5. The estimates are derived using equation (2) with a yield advantage (YA) figure of 1.40 and the proportion of land ($LHYT_T$) sown to HYV varities (category III) in Table C-6. The figures in Table C-6 are derived from Tables C-7 through C-9.

Table C-5 also includes an HYV wheat Production Index (PI) and is defined by equation (3):

$$PI = \frac{1}{(1 - k)} \qquad (3)$$

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Table C-5. Wheat Supply Parameter k and HYV Production Index.

Year	Supply Parameter k			Production Index		
	Category ‡ III	Category ‡ IV	Pakistan Total	Category ‡ III	Category ‡ IV	Pakistan Total
1964-65	.028	-	.028	102.9	100.0	102.9
1965-66	.077	-	.077	108.9	100.0	108.9
1966-67	.121	-	.121	113.8	100.0	113.8
1967-68	.138	-	.138	116.0	100.0	116.0
1968-69	.163	-	.163	119.6	100.0	119.6
1969-70	.172	-	.172	120.8	100.0	120.8
1970-71	.176	-	.176	121.3	100.0	121.3
1971-72	.183	-	.183	122.4	100.0	122.4
1972-73	.186	-	.186	122.4	100.0	122.4
1973-74	.187	-	.187	122.8	100.0	122.8
1974-75	.197	.006	.203	124.8	100.8	125.6
1975-76	.184	.025	.209	123.2	103.2	126.4
1976-77	.186	.037	.223	124.0	104.8	128.8
1977-78	.182	.046	.228	123.6	106.0	129.6
1978-79	.141	.092	.233	118.4	112.0	130.4
1979-80	.105	.139	.244	114.0	118.4	132.4
1980-81	.068	.182	.250	109.1	124.3	133.9

SOURCE: See Text in Appendix C

‡ Category III : Semi-dwarf (Pakistan/CIMMYT) HYV Varieties.
Category IV ; HYV Variety Introductions from other countries.

Table C-6 Percent Area Sown To Wheat HYV's, Pakistan

Year	Percent Area Sown To HYV's.		
	Category * III	Category * IV	Pakistan Total
	(Percent)		
1964-65	7.1	-	7.1
1965-66	20.7	-	20.7
1966-67	34.6	-	34.6
1967-68	40.0	-	40.0
1968-69	48.9	-	48.9
1969-70	52.0	-	52.0
1970-71	53.4	-	53.4
1971-72	56.0	-	56.0
1972-73	57.0	-	57.0
1973-74	57.0	-	57.0
1974-75	62.0	2.0	64.0
1975-76	58.0	8.0	66.0
1976-77	60.0	12.0	72.0
1977-78	59.0	15.0	74.0
1978-79	46.0	30.0	76.0
1979-80	35.0	46.0	81.0
1980-81	22.6	60.7	83.3

SOURCE: See Text in Appendix C

* Catagory III : Semi-dwarf (Pakistan/CIMMYT)
  Category IV : HYV Variety Introductions

Table C-7. Percent Area Sown To Tall and HYV Wheat, Punjab.

Year	Tall Varieties		HYV Varieties		
	Category I	Category II	Category III	Category IV	Pakistan Total
			(Percent)		
1955-56	100	-	-	-	-
1956-57	90	10	-	-	-
1957-58	85	15	-	-	-
1958-59	80	20	-	-	-
1959-60	78	22	-	-	-
1960-61	78	22	-	-	-
1961-62	77	23	-	-	-
1962-63	76	24	-	-	-
1963-64	75	25	-	-	-
1964-65	69	21	10	-	10
1965-66	50	21	29	-	29
1966-67	35	19	46	-	46
1967-68	33	18	49	-	49
1968-69	32	16	52	-	52
1969-70	31	16	53	-	53
1970-71	31	16	53	-	53
1971-72	28	14	58	-	58
1972-73	28	14	58	-	58
1973-74	27	14	59	-	59
1974-75	24	12	60	5	65
1975-76	23	10	57	10	67
1976-77	16	9	57	18	75
1977-78	16	9	55	20	75
1978-79	13	10	42	35	77
1979-80	10	7	30	53	83
1980-81	10	7	20	63	83

SOURCE: 1968-69 to 1980-81 Pakistan Total data from Agricultural Statistics of Pakistan, MFAC. Islamabad. All other data from Dr. N.I. Hashmi and Mr. S. Masood. NARC, Islamabad. Unpublished data collected by J.G. Nagy.

Catagory I; Pre Independence (1947-48) Varieties.
Category II; Post Independence - Pre Semi-dwarf Varieties.
Category III; Semi-dwarf (Pakistan/CIMMYT) HYV Varieties.
Category IV; HYV Variety Introductions from other countries.

Table C-8. Percent Area Sown To Tall and HYV Wheat, SIND.

Year	Tall Varieties		HYV Varieties		
	Category I	Category II	Category III	Category IV	Pakistan Total
			(Percent)		
1955-56	100	-	-	-	-
1956-57	90	10	-	-	-
1957-58	80	20	-	-	-
1958-59	70	30	-	-	-
1959-60	60	40	-	-	-
1960-61	50	50	-	-	-
1961-62	40	60	-	-	-
1962-63	30	70	-	-	-
1963-64	30	70	-	-	-
1964-65	30	70	-	-	-
1965-66	30	70	-	-	-
1966-67	30	65	5	-	5
1967-68	30	50	20	-	20
1968-69	27	28	45	-	45
1969-70	27	18	55	-	55
1970-71	27	13	60	-	60
1971-72	26	9	65	-	65
1972-73	24	8	68	-	68
1973-74	22	11	67	-	67
1974-75	14	4	81	1	82
1975-76	29	-	67	4	71
1976-77	23	-	73	4	77
1977-78	15	- -	80	5	85
1978-79	13	- -	62	25	87
1979-80	12	- -	49	39	88
1980-81	11	- -	28	61	89

SOURCE: 1972-73 to 1980-81 Pakistan Total data from Agricultural Statistics of Pakistan. MFAC, Islamabad. All other data from Mr. A.H. Natali, Wheat Botanist, ARI, Tandojam, Sind Unpublished data collected by J.G. Nagy.

Catagory I; Pre Independence (1947-48) Varieties.
Category II; Post Independence - Pre Semi-dwarf Varieties.
Category III; Semi-dwarf (Pakistan/CIMMYT) HYV Varieties.
Category IV; HYV Variety Introductions from other countries.

Table C-9. Percent Area Sown To Tall and HYV Wheat, NWFP.

Year	Tall Varieties			HYV Varieties		
	Category I	Category II	DIRK	Category III	Category IV	Pakistan Total
			(Percent)			
1955-56	100	-	-	-	-	-
1956-57	90	10	-	-	-	-
1957-58	80	20	-	-	-	-
1958-59	60	40	-	-	-	-
1959-60	40	40	20	-	-	-
1960-61	40	30	30	-	-	-
1961-62	40	20	40	-	-	-
1962-63	40	10	50	-	-	-
1963-64	40	10	50	-	-	-
1964-65	40	10	50	-	-	-
1965-66	40	10	50	-	-	-
1966-67	40	10	50	-	-	-
1967-68	30	10	50	10	-	10
1968-69	30	10	40	20	-	20
1969-70	25	10	35	30	-	30
1970-71	20	10	30	40	-	40
1971-72	20	5	30	45	-	45
1972-73	20	5	30	45	-	45
1973-74	20	6	30	44	-	44
1974-75	20	6	25	49	-	49
1975-76	20	4	15	61	-	61
1976-77	20	6	15	54	5	59
1977-78	15	8	15	52	10	62
1978-79	15	5	15	50	15	65
1979-80	15	6	15	49	15	64
1980-81	15	3	15	52	15	67

SOURCE: 1972-73 to 1980-81 Pakistan Total data from Agricultural Statistics of Pakistan, MFAC, Islamabad. All other data from Mr. Khan, Wheat Researcher, NARC. Unpublished data collected by J.G. Nagy.

Catagory I; Pre Independence (1947-48) Varieties.
Category II; Post Independence - Pre Semi-dwarf Varieties.
Category III; Semi-dwarf (Pakistan/CIMMYT) HYV Varieties.
Category IV; HYV Variety Introductions from other countries.

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where:

PI = the index of the percentage increase in production due to the use of HYV's (1963-64 = 100); and

k = as defined in equation (2).

To be compatible with the Akino and Hayami (1974) formulas given in Chapter 3.2, k is defined as a leftward shift from the post-innovation supply curve S_1 to the pre-innovation supply curve S_0. The Production Index is a k specified as a rightward shift and transformed into an index, 1963-64 = 100.

The use of category III HYV sown land in equation (2) results from the following discussion. The wheat varieties grown in Pakistan can be divided into four distinct groups in the Punjab and Sind and five groups in the N.W.F.P. The varietal groups are as follows:

Category I: Pre-independence (1947-48) varieties;

Category II: Post-Independence, pre-semi-dwarft varieties;

Category III: Semi-dwarf (Pakistan/CIMMYT) HYV varieties;

Category IV: HYV variety introduction from other countries; and

Category V: Dirk.

The varieties in groups I, II and V are tall varieties relatively unresponsive to fertilizer. The varieties in groups III and IV ar- semi-dwarf varieties and are responsive to fertilizer with two to three times the yield potential. The HYV's have their origin at CIMMYT in Mexico. Germplasm is developed at CIMMYT and sent to Pakistan and other countries where some selective breeding is done before the varieties are released. The objective in this study, as

explained in Chapter 1, is to only include those varieties in the analysis that the Pakistani Research System has contributed to. Thus, the total percentage of HYV acreage is split into categories III and IV.

The total percentage of HYV acreage in Pakistan (except for earlier years) is obtained from various issues of The Agricultural Statistics of Pakistan. The splitting of varieties into Groups I through V are estimates of research scientists and their colleagues who have experience and a historical perspective of Pakistan's wheat industry. The method of estimating the percentage of hectares in each varietal group is admittedly crude; however, with the aid of the published data, the research scientists' experience and common logic, the figures should portray a reasonable sketch of what has taken place. A separate table for the Baluchistan varietal grouping is not available. The total Baluchistan HYV acreage is used as category III.4/ This should not bias the overall Pakistan category III figures up by very much on two accounts. First, a minimal amount of category IV varieties are grown in Baluchistan, and secondly, Baluchistan produces only 2.0 percent of all wheat in Pakistan.

Table C-10 presents a list of the varieties in each of the five categories by province and the dates of their release or introduction in Pakistan.

4/ The percent of HYV varieties in Baluchistan for the period 1972-73 to 1980-81 are as follows: 10, 9, 15, 23, 18, 39, 39 and 42 percent respectively (Agr. Statistics of Pakistan, 1981).

The Shift Parameter for Maize

An estimate of the maize shift parameter for the Punjab, N.W.F.P. and all Pakistan (Punjab plus N.W.F.P.) is given in Table C-11. The estimates are derived with yield advantage (YA) figures of 1.16 and 1.24 for the Punjab and a 1.16 for N.W.F.P. For the all Pakistan region, a 1.16 and a 1.16 + 1.24 weighted by provincial HYV hectares are used as YA. The proportion of land sown to HYV maize varieties by year ($LHYV_T$) is given in Table C-12. There are no official estimates of the hectares sown to maize HYV varieties. The estimates in Table C-12 were formed from interviews with scientists and extension people knowledgeable about maize, in particular Dr. M. Oasim Chatha, National Coordinator, Maize, Sorghum and Millet, NARC, Islamabad.

To be compatible with the Hayami and Herdt (1977) formulas used in Chapter 3.4, k is constructed as a rightward shift from the pre-innovation supply curve S_0 to the post-innovation supply curve S_1 in Figure 3.3. The k values in Table C-11 are therefore the percentage increase in production that did result from the adoption of HYV maize. The construction of k is therefore YA x $LHYV_T$. One could then construct a maize HYV production index as was done for wheat by multiplying by 100.

Table C-13 presents the names of the HYV varieties released and grown in the Punjab and N.W.F.P. There is no introduction category as there is for wheat because the varieties are all CIMMYT/Pakistan varieties. As noted in Table C-13, maize is a very location specific

Table C-10 Pakistan Wheat Varieties by Category

Variety Categories 1/				
I	II	III	IV	V
Punjab and NWFP Varieties				
8A (1911) 2/	C-271 (1955)	Mexi-pak (1965)	Yecora (1974)	Dirk (1958)
9D (1911)	C-273 (1957)	Khushal-69 (1969)	Nuri (1975)	
P-11 (1913)		Barani-70 (1970)	Arz (1976)	
A-H (1917)		Chenab-70 (1970)	HD 2009 (1978)	
C-518 (1933)		Blue Silver (1971)	WL-711 (1978)	
C-591 (1934)		SA-42 (1972)	Sonalika (1978)	
C-228 (1941)		Pothowar (1973)	Pavon (1978)	
C-250 (1944)		Tarnab-73 (1973)		
C-217 (1944)		Sandal (1973)		
Others (Desi)		LYP-73 (1973)		
		Pari-73 (1973)		
		SA-75 (1975)		
		LU-26 (1976)		
		Punjab-76 (1976)		
		Indus-79 (1979)		
		Balawalpur-79 (1979)		
		Punjab-81 (1981)		
		Pak-81 (1981)		
Sind Varieties				
C-591 (1934)	H-68 (1955)	Mexi-Pak (1965)	Yecora (1974)	
Others		Pak-70 (1974)	Pavon (1978)	
		ZA 77 (1979)	Sonalika (1978)	

Sources: Dr. N. I. Hashmi, Mr. Shahid Masood and Mr. Khan, NARC Islamabad and Mr. A. H. Natali, ARI, Tandajam.

1/ Category I - Pre-Independence (1947-48) Varieties.
Category II - Post-Independence - Pre Semi-dwarf Varieties.
Category III - Semi-dwarf (Pakistan/CIMMYT) Varieties.
Category IV - HYV Variety introductions from other countries.
Category V - Dirk (Australian Tall Variety Introduction).

2/ Year released or introduced in Pakistan.

Table C-11 Maize Supply Shift Parameter k

Year	Punjab YA=1.16	Punjab YA=1.24	NWFP YA=1.16	Pakistan YA=1.16	Pakistan YA=weighted 1.16 + 1.24
	(Percent)				
1967-68	0.8	1.2	0.8	0.8	1.0
1968-69	1.1	1.7	1.0	1.0	1.4
1969-70	1.4	2.2	1.0	1.2	1.6
1970-71	1.8	2.6	1.1	1.4	1.9
1971-72	2.2	3.4	1.4	1.8	2.4
1972-73	2.7	4.8	1.6	2.1	3.2
1973-74	3.2	4.8	2.1	2.6	3.4
1974-75	4.0	6.0	2.4	3.1	4.2
1975-76	4.8	7.2	3.0	3.9	5.1
1976-77	5.6	8.4	3.4	4.4	5.9
1977-78	6.6	9.4	4.2	5.3	7.0
1978-79	7.4	11.0	4.6	6.0	7.8
1979-80	8.5	12.7	5.6	6.9	9.2
1980-81	9.6	14.4	6.4	7.9	10.4

Note: See text for calculation of shift parameters.

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Table C-12 Proportion of Total Maize Hectares Sown to HYV's

Year	Percentage Hectares Sown to HYV's		
	Punjab	NWFP	Total
	(Percent)		
1967-68	5	5	5
1968-69	7	6	6.5
1969-70	9	6	7.4
1970-71	11	7	8.9
1971-72	14	9	11.3
1972-73	17	10	13.1
1973-74	20	13	16.1
1974-75	25	15	19.5
1975-76	30	19	24.3
1976-77	35	21	27.6
1977-78	41	26	32.9
1978-79	46	29	37.3
1979-80	53	35	43.7
1980-81	60	40	49.7

Source: No official estimates of the percentage hectares sown to HYV maize exist. The above trend estimates were formed from interviews with scientists and extension people knowledgeable about maize production in Pakistan.

Table C-13 HYV Maize Varieties Sown in Pakistan

Province	Variety 1/	Year Released	Type
Punjab	Syn-551	-	Yellow
	Neelum	1970	Yellow
	Agaiti-72	1972	Yellow
	Akbar	1973	Yellow
	Sardaf	1975	White
NWFP	Swabi (white)	1961	White
	Syn-66	1966	White
	Zia	1974	White
	Sarhad (yellow)	1974	Yellow
	Shaheen	1974	White
	Khyber	1974	White
	Sarhad (white)	1976	White
	Changez	1976	White

Source: Qasim, M. C. and Rehman, H., "Maize Production and Research in Pakistan," Progressive Farming, PARC, Islamabad, May-June 1981.

1/ All varieties a synthetics, while varieties are fairly province specific, there is some crossover between provinces.

crop and different varieties are released and adopted in each province. A interesting thing to note is that none of the varieties are hybrids. Although some research on hybrids is done, most research is done on synthetic varieties that unlike hybrids can be used by farmers for seed. Because hybrid seed needs to be bought every year by farmers, any research thrust in this area would have to be accompanied by a seed multiplication, marketing and distribution system far beyond the capabilities of the existing system. For this reason, research has mainly been done on synthetics.

APPENDIX D

Wheat and Maize Supply and Demand Elasticities

The calculation of the change in producer and consumer surplus using the formulas given in Chapter 3 require the specification of the commodity supply and demand elasticities.

The Supply Elasticities

The formulas for calculating producer and consumer surplus as given in Chapter 3 requires production response elasticities. However, because of the difficulties of estimating production response elasticities, all the supply response work in Pakistan concentrates on acreage response. Acreage response elasticities are a good measure of production response only when the yield response to price is small. This is so because the production response price elasticity can be decomposed into an acreage response price elasticity and a yield response price elasticity as outlined by the following.

Holding all other relevant supply response variables constant, output (Q) is a function of area planted (A) and yield (Y) as in equation (1) (see Yotopoulos and Nugent, 1976, page 137).

$$Q = A \cdot Y \qquad (1)$$

Given that both the area planted and the yield obtained from the planted area are both functions of price, totally differentiating with respect to price results in equation (2)

$$\frac{dQ}{dP} = Y \frac{\partial A}{\partial P} + A \frac{\partial Y}{\partial P} \qquad (2)$$

By dividing equation (2) by Q/P, the response of output, acreage and yield to price can be expressed as: the total output elasticity α_{QP}; the acreage elasticity α_{AP} and the yield elasticity α_{YP}.

$$\alpha_{QP} = \alpha_{AP} + \alpha_{YP} \qquad (3)$$

As can be seen from equation (3), a zero or non-negative yield response price elasticity results in the acreage response price elasticity as being the lower bound estimate of the total output elasticity.

Table D-1 includes the available wheat and maize acreage response estimates for Pakistan and the Punjab. The previous discussion suggests that if the yield response elasticity is minimal, the acreage response elasticities are a good approximation of the total output elasticity. However, when there exists the ability to substitute land area for other inputs such as fertilizer, new seeds, irrigation and labor, yield responses to price may be significant.

The yield responsiveness to own price may be empirically tested. Houck and Gallagher (1976) tested USA corn yield response equations finding the fertilizer corn price ratio to be significant over the years 1951 to 1972; fertilizer being the dominant input that is substituted for land. Menz and Pardey (1983), using a similar analysis over the 1972-80 period did not detect a significant fertilizer corn price ratio.

Falcon (1964) sums up his feelings on yield response to price in (West) Pakistan as follows:

> "....there is likely to be little year-to-year change in relative yields in response to expected relative price changes between food and cash crops, or even between two cash crops. In addition,

there is likely to be little relationship between changes in yields and changes in the prices of agricultural outputs relative to the price of inputs. Severe capital rationing, the fixed and limited nature of most resources, physical unavailability of many factors, and ignorance of better farming methods militate against such responses. Major yield changes are caused more significantly by climatic variations, waterlogging and salinity, pests, etc." 1/

Falcon's study detected a large acreage response to price for cotton, but a negligible yield response to price. However, a study on Indian cotton by Krishna (1963) did find a yield response to price.

Falcon's study, however, is prior to the green revolution with the introduction of HYV's and associated technological packages. The question is, were the new technologies adopted because of price expectations or was the adoption independent of price and adopted when they became physically available and understood? The latter argument was used by Behrman (1968, page 154) in analyzing his empirical results that suggested a zero or low yield response to price for crops in Thailand.

Following the model of Houck and Gallagher (1976), a Pakistan wheat yield response equation was estimted to empirically test yield response to price. An equation was estimated with yield as a function of the fertilizer/wheat price ratio, land, a weather variable and various technology trend variables over the years 1965-66 to 1980-81. The results (not presented) indicated either a significant but (incorrect) positive sign on the fertilizer/wheat price ratio or a (correct)

1/Although Falcon believed there to be little yield response to price in Pakistan, he was not giving the structuralists' ammunition to say that LDC farmers do not respond to economic incentives. Falcon believed that, given the opportunity, farmers do respond to economic incentives.

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Table D-1 Wheat and Maize Price Elasticities of Acreage Response

Crop and Region	Period of Estimation	Short-run Elasticity	Source
1. Wheat			
Pakistan (both log and linear)	1957-58 to 1979-80	0.25	Ashiq (1981)
Pakistan	1944 to 1959	0.20	Falcon (1964)
Punjab (India-Pakistan)	1914 to 1943	0.08	Krishna (1963)
Punjab (India)	1960-61 to 1969-70	0.08	Kaul & Sidhu (1971)
Punjab (India)	1950 to 1967	0.10	Cummings (1975)
Pakistan	1949 to 1968	0.10	Cummings (1975)
2. Maize			
Pakistan (both log and linear)	1957-58 to 1979-80	0.08	Ashiq (1981)
India-Pakistan	1914 to 1943	0.23	Krishna (1963)
Punjab (India)	1960-61 to 1969-70	0.12	Kaul & Sidhu (1971)

Source: Ashiq (1981).

negative sign but non-significant coefficient on the fertilizer/wheat price ratio.2/

Disregarding the results with the positive sign on the fertilizer/wheat price ratio, the results suggest that the acreage response elasticities could be used as approximations for the total output elasticity. This conclusion, however, is based on a fairly naive model as well as on questionable data. For instance, Pray (1978) suggests that the official Pakistan wheat yield statistics (which were used in the analysis) may be in error.

Because of the lack of good hard evidence on the yield responsiveness to price for wheat and maize, which would require substantial work, data and perhaps a better methodology than is presently available, the following will be used. A 0.30 wheat elasticity will be used in the analysis as the base supply elasticity. This is based on the 0.25 wheat acreage elasticity of Ashig (1981) which is used as the lower bound estimate. Thus a 0.30 figure leaves some lattitude for yield being responsive to price.

The maize supply elasticity of 0.08 by Ashig will be used as a lower bound estimate for the total Pakistan estimate. A figure of 0.15 will be used as the base supply elasticity around which a range of figures will be used in a sensitivity analysis.

2/To state that a positive sign on the fertilizer/wheat price ratio is incorrect depends on the situation. A positive sign simply means a negative effect of price on yield which can come about as described by Barker (1966), indirectly through the acreage response. An increased relative price of a commodity may lead to an increased area being sown, but if some or all of the increased area is inferior to the present sown area, the average yield may drop.

Supply elasticities for maize do not exist for each province separately. However, an approximation can be calculated. From the identy in equation (4):

$$Q_T = Q_P + Q_N \qquad (4)$$

where Q_T is the total maize production in Pakistan and Q_P and Q_N are the maize production in the Punjab and NWFP respectively, equation (5) may be derived:3/

$$\gamma_t = \alpha\gamma_p + (1 - \alpha)\gamma_n \qquad (5)$$

where γ_t, γ_p and γ_n are the elasticities of the three regions and α is the proportion of production from the Punjab region (Scobie and Posada, 1971, page 54). The elasticity γ_t is known (0.15) as is α which over the years is .47 to .49 (Agricultural Statistics of Pakistan, 1981). The elasticities γ_p and γ_n are not known, however, since α is about .5 and the two regions are subject to similar conditions and agricultural policies, equal elasticities of .075 will be used for γ_p and γ_n.

The Demand Elasticities

Two demand elasticities for wheat have been estimated for Pakistan. A study by Bissink (1970) using a Frisch scheme with household survey data for 1963-64 estimated a -0.10 own price elasticity. Bengali (1983) used time series data from 1956-57 to 1979-80 and estimated

3/Equation (5) is obtained from equation (4) by first taking the partial derivative of (4) with respect to price (price being the same in both markets) and then converting the resulting expression into elasticities by multiplying through by P/Q_T and then multiplying the first term on the right hand side by unit ratios Q_P/Q_P and the second term by Q_N/Q_N. Rearranging and collecting terms results in equation (5).

own price elasticities ranging between -0.103 and -0.150 which were statistically significant at the 10 percent level.

Estimates of a maize demand elasticity for Pakistan were not to be found. The elasticity would likely be fairly inelastic; imports and exports of maize are not allowed, maize occupies third place after wheat and rice in its per capita consumption and maize is a small cost component in the breakfast and starch industry. Demand elasticities of maize for LDC countries are also usually less than a third in absolute value (Scandizzo and Bruck, 1980). A range of elasticities around -0.10 will be used (as a sensitivity analysis) when calculating the producer and consumer surplus from the formulas in Chapter 3.

APPENDIX E

The Wheat Pricing and Marketing System

Table E-1 presents wheat production, domestic procurement and imports by year for 1960-61 to 1980-81. As noted, Pakistan is a wheat deficit country and produced from 80 to 95 percent of its requirements over the period 1970-71 to 1980-81. Imports, largely through PL-480 programs made up the deficit of 5 to 20 percent depending on the yearly harvest size. Pakistan also has a domestic procurement program that procures from 2 to 26 percent of the yearly production. Since the Pakistan government is the sole importer of wheat and exports are banned, the two programs of domestic procurement and importing leave the government in direct control of 20-35 percent of the total yearly available supply of wheat (in the 1970-71 to 1980-81 period).

Table E-1 also presents the unit value of wheat imports in Rs./tonne basis Karachi. The governments ban on wheat exports and its import and price procurement policies has produced a gap between producer prices and the world price over the years 1972-73 to 1980-81. Previous to 1972-73, the domestic procurement price has been above the world import price basis Karachi. Much of the imported wheat comes from the PL-480 program with different terms than might be expected from a regular wheat purchase in the world market. Thus, it is not clear that the unit value expressed in table E-1 is as high as the price that would have to be paid in the open world market. Although it may seem cheaper to have bought imported wheat than to procure it

Table E-1 Pakistan Wheat Statistical Data; 1964-65 to 1980-81

Year	Production (1)	Internal Procurement (2)	Column (2) as % of Column (1) (3)	Imports (4)	Column (4) as % of Column (1) (5)	Total Available Wheat (1) + (4) (6)	Wheat Controlled by Government (7)	Column (7) as % of Column (6) (8)	World Wheat Price (Karachi) (9)
	(In 000's tonnes and percentages)								(Rs./tonne
1964-65	4,591	1	-	1,516	33.0	6,107	1,517	24.8	352
1965-66	3,916	1	-	756	19.3	4,672	757	16.2	327
1966-67	4,335	21	-	1,163	26.8	5,498	1,184	21.5	344
1967-68	6,418	9	-	1,441	22.5	7,859	1,450	18.5	390
1968-69	6,618	794	12.0	16	-	6,634	80	12.2	343
1969-70	7,294	907	12.4	230	3.2	7,524	1,137	15.1	360
1970-71	6,476	1,017	15.7	285	4.4	6,761	1,302	20.1	366
1971-72	6,890	841	12.2	690	10.0	7,580	1,532	22.2	391
1972-73	7,442	208	2.8	1,359	18.3	8,801	1,567	21.1	818
1973-74	7,629	1,342	17.6	1,229	16.1	8,858	2,571	33.7	1,258
1974-75	7,674	1,253	16.3	1,344	17.5	9,018	2,597	33.9	1,831
1975-76	8,691	1,236	14.2	1,186	13.7	9,817	2,422	27.9	1,505
1976-77	9,144	1,276	25.9	499	5.5	9,643	2,875	31.5	1,322
1977-78	8,367	1,842	22.0	1,052	12.6	9,419	2,894	34.6	1,271
1978-79	9,950	1,086	10.9	2,236	22.5	12,186	3,322	33.4	1,567
1979-80	10,857	2,376	21.9	602	5.6	11,459	2,978	27.4	1,729
1980-81	11,473	2,954	25.8	305	2.7	11,778	3,259	28.4	2,075

Sources: Columns (1), (2) and (4), Agricultural Statistics of Pakistan, GOP, Islamabad.
Column (9), Pakistan Economic Survey, GOP, Islamabad.

internally, the addition of incountry transportation, handling and bagging costs would bring the price up to or past the procurement price levels prior to 1972-73. For example, the 1966-67 cost of transportation, handling and bagging was 80 Rs./tonne (Stern, Falcon, Gotsch, 1969, p. 3) which brings the cost of an imported tonne of wheat above the procurement price.

For purposes of discussion the wheat pricing and marketing system is outlined under the following headings; the wheat ration program, wheat procurement and procurement price, the free market system for wheat and flour and a section ending in a general discussion.

The Wheat Ration Program

The wheat ration program is described by Khan (1982, p. 1) as follows:

> "Wheat flour (atta) is distributed to consumers in the urban and wheat deficit rural areas through a network of ration depots which are owned and operated by private individuals. The Provincial Governments issue licences to operate ration depots and also issue ration cards to heads of the families to obtain ration atta. The distribution scale is 7.5 kilograms per adult per month (half of the scale per minor). The distribution scale is different for big cities, small towns, and rural areas. The ration depot owners indent supplies from Roller Flour Mills against cash payment once every two weeks. The Roller Flour Mills receive wheat from Government stocks. A depot holder indents, supplies on the basis of his allocation and sales during the past two weeks. The officials of Provincial Food Departments check the stocks and sales of each depot holder.
>
> The margin of the depot holder is the difference between the fixed price at which he buys atta from Roller Flour Mills and the fixed price at which he sells to the ration card holders. In addition, he receives the empty bags which constitutes a large part of his total profit. The price differential is Rs.1 per 100 kg of atta and the price of empty bag varies from Rs.6 to Rs.10.

> The present system of rationing does not meet the full atta requirements of the ration card holders. Additional requirement of atta are purchased from the open market at price higher than the ration depot price."

The ration program has all the ills that one might expect from such a program. As Turvey and Cook (1976, p. 104) point out, ration card holders can cheat the system by overstating the number in the household, multiple registration within one household and possession of more than one ration book. On the other hand, depot holders can overstate the quantity issued, retain defunct cards, underweight or adulterate atta and sell the atta on the open market.

Wheat Procurement and Procurement Price

The procurement policy of the Central Government is to set an annual procurement target for each province, set a national procurement price and decide on the amount to import to balance out the deficit. The Provinces are responsible for the administration, procuring wheat, setting up the ration shops and arranging for milling (Turvey and Cook, 1976).

Wheat is procured at a number of procurement centers throughout each province and concentrated mainly in wheat surplus producing areas. A Government of Pakistan study on food procurement (GOP, 1975) for the 1974-75 crop detailed the procedure for procurement for the Punjab as follows;

(i) Government purchases wheat of the prescribed standard that may be voluntarily offered by growers/trade at the support price of Rs.37 per maund subject to quality deduction.

(ii) The purchasing centres last year were 800. This year, the centres have been reduced to 475 to concentrate mainly in the surplus wheat producing areas.

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(iii) Payment to growers is made in full on the spot immediately on delivery.

(iv) Traders/arhtis are paid 97% price immediately on delivery and balance 3% after assessment of quality.

(v) With a view to facilitating payment to the sellers commercial banks have been appointed as paying agents for making spot payments.

(vi) Transportation of wheat/wheat atta including fine atta by any means of transport from any district to a place outside the boundary of a district has been banned. This restriction will, not however, apply on movement of Government account or on the authority of a permit issued by the Government and by a bona fide traveller provided the quantity does not exceed 10 seers (29.17 seers = 1 bus.).

(vii) There is no ban on private trading in wheat.

(viii) The roller flour mills will not purchase any wheat from the open market during the procurement period. This agreement has been obtained by pursuation and not under any legal cover. In return, Government have agreed to supply them reasonable quantity of wheat from their stocks for sale in the open market.

While the price support in (i) and the number of purchasing centers in (ii) have changed, the basic procurement procedure is the same today for the Punjab as well as for the other provinces with one exception. The exception is that the N.W.F.P. has no inter-district restrictions on movement except to the tribal areas.

In 1980-81, about 80 percent of the total Pakistan wheat procured came from the Punjab with about 18.5 percent from the Sind and 1.0 and 0.05 from the N.W.F.P. and Baluchistan respectively.

The Free Market System for Wheat and Flour

Besides the government procurement centers, farmers market their wheat through any one of the following:

1) Agents that come directly to the farm.

2) Local village mandi (market).

3) The central or large town mandi (Commission agents).

4) Cooperative societies.

5) Directly to mills.

A survey sponsored by the Agriculture Prices Commission (1981) of 496 farms in the Punjab that had access to a Government procurement centre found that 53 percent of the wheat was sold in a village mandi, 31 percent to the Procurement Centers and 11 and 4 to the Commission agents and Cooperative Societies respectively. At the time of the survey, 76 percent of the marketable surplus had been sold.

A small amount of wheat seems to move from farmers to large mills directly. The wheat is ground into flour in local mills and distributed locally or in large mills and the flour sold to wholesalers and then to retailers.

The survey sponsored by the agricultural prices Commission also surveyed prices received by wheat producers by source of sale. Gross prices in Rs./40 kg were 55.30, 56.80, 57.98 and 57.85 and net prices were 55.08, 53.64, 56.35, and 55.77 for the Village, Commission agent, Procurement Center and Cooperative Society respectively. The net prices are gross prices minus transportation cost, quality deductions and commission fees.

The survey shows both gross and net Procurement centre prices to be the highest but only obtaining 31 percent of the market. Producers gave the following responses as to why they did not market more at the

Procurement Centres. First, quality deductions were 2.5 times higher at Procurement Centers and many producers thought that it was even higher thereby making the procurement price lower. Secondly, there was a high rate of rejection of producer grain on a quality basis at the Procurement Center whereas the same grain was accepted by the Village mandi. The Village Mandi however could blend different qualities of grain together and sell that to the Procurement Centers Thirdly, delays up to 15-20 days in payment by Procurement Centers made producers nervous. Fourthly, wheat had to be delivered to Procurement Centers in bags which was not a requirement of the other markets.

General Discussion

The focal point of the discussion is to determine if the Pakistani wheat price is above or below the post-innovation HYV market equilibrium price (P_1 in figure 3.2) so as to establish the procedure to measure the change in surplus from a righward shift in the supply curve from the use of HYV's.

The procurement price is often thought of as a support price to producers so that prices do not drop to low because of the ban on exports. The fact that the government enters the market and purchases wheat at the procurement price suggests that it is a support price and that it would be above the market equilibrium price P1 in figure 3.2

However, Procurement centers will not buy all grain offered to them but have targets and limits with respect to storage capacity. In

fact, procurement targets are often not met and "Rather than raise the price, the authorities impose restrictions on movement or make procurement quasi-compulsory. Instead of improving the market they thus sometimes rig it in their favor" (Turvey and Cook ,1976, p. 114). The rigging corresponds to items (vi) and (viii) of the procedures for procurement in the section on Wheat Procurement and Procurement Price. Since most procurement centers are located in surplus wheat growing areas, the transportation restrictions along with flour mills not able to buy wheat in the market during the procurement period leaves the Procurement Center in a better position.

There is also the fact that Pakistan does import wheat and any price support effect by the procurement price is negated or partially negated by these imports. Although not stated as an explicit policy, the government is in a limited way in the business of price stabilization as evidenced by the following quote from a government publication. "To contain wheat prices in the open market within reasonable limits, the Government released more wheat in the market as well as to the ration depots (Pakistan Economic Survey, 1981-82, p. 19). The fact that wheat procurement procedures at times must be rigged and imports are used to contain prices in the open market suggests that the procurement price is below the equilibrium price P_1 in Figure 3.2.

The Pakistan wheat situation corresponds somewhat to the Japanese rice situation. Prior to 1960, Japan imported 5 to 20 percent of its rice and in their analysis on the returns to rice research in Japan, Akino and Hayami (1975, p.4) suggest that "In spite of the occasional price support operations, the actual level of rice prices in Japan

before 1960 should have been below market equilibrium in autarky."

A reliable producer price for wheat does not exist thus the procurement prices will be used in the analysis in Chapter 3.3. The Prices Commission survey suggests that producer prices do not devi___ substantially from the procurement price although it is a common concensus that at times producer prices on average are a bit higher. However as stated before, producer prices are kept in check by procurement procedures and imports.

Table F-1 DISEASE REACTION OF COMMERCIAL WHEAT VARIETIES

Disease / Variety	Stripe rust	Leaf rust	Stem rust	Flag smut	Loose smut	Complete Bunt	Karnal Bunt (Partial Bunt)	Powdery mildew
I. RECOMMENDED a/								
Normal Duration								
Lyallpur–73	30S	5MS–S	0	S	S	S	S	S
Pavon –76*	80S	MR	R	S	S	S	–	MS
WL –74*	50MS-S	5MR	20S	S	S	R	S	VS
Medium Duration								
Pari –73	I–MR	5MR	10MR	S	–	S	S	S
Yecora –70	60S	20MS	80S	S	S	S	I	MS
Nuri –70	50S	40MR	10MS	S		S	S	MS
Ari*	I–MS	20MR	0	S	S	S	–	VS
Sandal	20M–S	20MS-S	20MS-S	S	S	S	S	VS
Short Duration								
LU –26	50–S	20MR-MS	TR	S	–	S	–	MS
Blue Silver	T–MS	30MR	10MR	S	R	S	S	S
Sonalika*	T–MS	20MR	0	S	S	S	S	VS
II. WITHDRAWN								
Local White	100S	100S	90S	R	–	S	–	MS
C591	100S	60S	80S	S	S	S	S	MR
Punjab–76	100S	100S	20MR	S	S	S	–	MS
Mexi-Pak	100S	90S	20MR	S	S	R	S	MS
Pothwar	90S	60S	50S	S	S	S	S	MS
Tarnab 73	60S	100S	5MR	S	S	S	S	VS
Khushal 69	80S	100S	20MR	S	S	S	S	S
HD 200g*	70S	10R	20S	S	S	S	S	VS
Barani 70	5S	100S	T–MR	S	R	S	S	VS
Pak 70	40S	100S	10MR	S	–	S	S	MS
Chenab 72	60S	100S	5MR	S	S	S	S	VS
SA 42	30MR	100S	30M	S	S	S	S	MS–S
SA 75	20MS	70S	5MR	S	S	S	S	MS–S

R – Resistant
MR – Moderately Resistant
MS – Moderately Susceptible
T – Traces
S – Susceptible
VS – Very Susceptible
I – Intermediate

Source: Amir Muhammed, National Wheat Perspectives, August 1979, PARC.

a/ The varieties Yecora and Nuri are no longer recommended varieties.

smuts, bunts and powdery mildew. Also most of the recommended varieties are somewhat susceptible to the rusts. Of all the recommended varieties, Lyallpur-73 is the variety that is now recommended the most.

Another response to the rust epidemic was to zone Pakistan's wheat growing areas into wheat production zones largely on the basis of rust incidence and type. Again this underscores the need for location specific research that will provide the best variety available to different areas in the country. As a result of importing varieties from other countries (Introductions) because of the rust epidemic, these Introductions now are sown on a large portion of the wheat cropped area. Tables C-7, C-8, and C-9 in Appendix C indicate that Introductions (Category IV) made up 63, 15 and 61 percent of the percentage of hectares sown to wheat in the Punjab, N.W.F.P. and Sind in 1980-81 respectively. It was fortunate that the Introduction varieties were available although table F-1 suggests that they are not superior with respect to disease resistance than Lyallpur-73, a Pakistan/CIMMYT variety released in 1973.[2/] Had the agricultural education, research, extension and seed multiplication system been working to produce disease resistant varieties prior to the wheat rust epidemic, much of the loss in production could have been avoided in

2/ Several arguments exist against importing other countries' varieties. First, there is the danger of importing weed seeds and diseases not common to your country. Secondly, if a crisis situation exists, there are no assurances of quality and timeliness of seed imports and the risk exists that the varieties may not grow well because of location specific problems. Thirdly, as in the case of the gram blight (next section) the luxury of importing better varieties may not exist.

1977-78 as could have the need to import seed wheat and wheat for human consumption

A calculation can reveal the monetary loss to the Pakistan economy of not having in place less susceptible rust varieties. In 1978-79 Pakistan imported 1.96 million tonnes of wheat (Table 1.3). It is reasonable to assume that in the event that Pakistan had more rust resistant varieties, that some wheat would have been imported anyway as in the previous years and that although rust resistant varieties existed, they would not be 100 percent resistant. To account for this, an assumption is made that Pakistan would have imported the same amount that was imported in 1976-77 which was 1.05 million tonnes. Thus, the assumption is made that 0.91 million tonnes (1.96 - 1.05) was imported as a direct result of the rust epidemic. The 0.91 million tonnes is valued at Rs. 1,157 million (U.S. $116.8 million)[3/] and is the cost to the Pakistan economy for not spending sufficient funds and effort on rust resistant variety research. In the same year that Pakistan spent the Rs. 1,157 million on importing wheat because of the rust epidemic, only Rs. 257.5 million (U.S. $26.0 million) (table B-3) was spent on the entire agriculture research and extension program in Pakistan. Because rusts are cyclical and will return at a future date, Pakistan should be willing

3/ A value of Rs. 1,271/tonne (Table E-1) was used in calculating the value of the 0.91 million tonnes. The official exchange rate of Rs. 9.9/U.S. $1.00 was used in converting the rupees to U.S. dollars.

to increase the expenditure on wheat rust research and extension and other wheat diseases and strengthen research establishments like the CDRI.

The Gram Blight in Pakistan

Gram (chickpea) is another important food crop in Pakistan. An average 1,123 thousand hectares are sown to gram each year and is the fourth largest area sown to a single crop after wheat, cotton and rice. Table F-2 presents the area sown, production and yield of gram over the period 1970-71 to 1980-81. There has been a 3.7 percent growth rate in the area sown to gram over the 1970-71 to 1978-79 period, however, production has only a slight upward trend as does yield/ha. Yield/ha is virtually stagnant and the five year averages of 507 kg/ha and 544 kg/ha for 1965-70 and 1970-75 respectively are surprisingly lower than the 1947-1951 five year average of 601 kg/ha. This basically means that most of the increased production is coming from increased area sown and not from increased yield/ha.

Table F-2 also portrays the consequences of the gram blight in 1979-80. Yield fell to 278 kg/ha and production to 313 cutting the average per capita consumption of 6.68 kg/annum to 3.81 kg/annum. By 1980-81 the yield had gone back up to 400 kg/ha but this was not a result of introducing blight resistant gram varieties from other countries but a result of a cutback in hectares sown by the farmers in the area of the worst infestations. Only 843 thousand hectares were sown in 1980-81. Unlike the case of wheat rust, there were no readily available varieties to import from other countries. This is another

Table F-2 Area, Production and Yield of Gram in Pakistan

	Area Sown ('000' hectares)	Production ('000' tonnes)	Yield (kg/ha)
1947-51 Average	991	606	601
1965-70 Average	1,064	538	507
1970-71	914	494	544
1971-72	964	510	526
1972-73	1,017	553	544
1973-74	1,108	610	553
1974-75	996	550	533
1970-75 Average	1,000	344	544
1975-76	1,068	601	563
1976-77	1,095	649	593
1977-78	1,099	614	558
1978-79	1,224	538	439
1979-80	1,129	313	278
1975-80 Average	1,123	458	484
1980-81	843	337	400

Source: Agricultural Statistics of Pakistan, 1981, GOP Ministry of Food, Agriculture and Co-operatives, Islamabad.

Pakistan Basic Facts, 1980-81, GOP, Finance Division, Islamabad.

case where science-based agriculture could have prevented a crisis had the agricultural education research and extension system been fully operative. As a consequence of the gram blight, gram had to be imported and the wholesale price went up from Rs. 82.23/40 kg in 1979-80 to Rs. 187.3/40 kg in 1980-81, an increase not shown by any other food crop in Pakistan (Pakistan Basic Facts, 1980-81, p. 125).

In summary, the agricultural education, research and extension system has failed to increase the yield of gram in Pakistan. It has also failed to deal with the gram blight that reduced production in 1979-80 to almost one-half of the average production of the four earlier years. This suggests a greater commitment to the agricultural education, research and extension system is necessary in an effort to increase gram yields and disease resistance.