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AGRICULTURAL RESEARCH PRODUCTIVITY IN PAKISTAN

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ABSTRACT

Productivity growth is an important component of economic growth in agriculture. Agricultural research programs have been shown in a number of studies to have contributed to productivity growth (see Evenson and Pray 1990 for a summary). This study is one of the first to quantify the economic impacts of agricultural research in Pakistan.

Chapter I presents an overview of the research institutions in Pakistan and documents changes in the system associated with the development of the Pakistan Agricultural Research Council (PARC). Characteristics of the System are discussed and some of these are subjected to further analysis in later chapters.

Chapter II develops and reports both Partial Factor Productivity (PFP) and Total Factor Productivity (TFP) indexes for Pakistan agriculture. These indexes are computed for most districts for the 1955-56 to 1985-86 period. This chapter also reports a comparison of TFP changes in the Indian state of Punjab and the Pakistan provinces utilizing comparable computational methods and data.

Chapter III reports a statistical analysis of the determinants of TFP change at the district level. This analysis is comparable to studies in other countries usually referred to as "TFP decomposition" studies. The analysis estimates the contribution of research and infrastructure investments to productivity growth.

Chapter IV reports statistical analysis of PFP indexes (yields) for several crops. This analysis is more complex than the TFP analysis and provides additional insight into the role of research programs because differences between crop research programs can be observed.

The final chapter analyzes the economic implication of the estimated parameters. Estimates of benefits based on total (i.e., producer plus consumer) surplus are utilized to compute marginal internal rates of return (MIRRs) to investment in research. International comparisons with other studies are also provided.

KEY WORDS: Research, Productivity, Agriculture, Pakistan

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INTRODUCTION AND OVERVIEW

Productivity growth is an important component of economic growth in agriculture. It has been shown in a number of studies that agricultural research programs have contributed to productivity growth.[1] This study is one of the first to quantify the economic impacts of agricultural research in Pakistan.

Nagy (1990) reports a study of the impacts of wheat research from 1964-81, maize research from 1967-81, and an aggregate productivity study for the 1959-60 to 1978-79 period. The latter study was based on a productivity measure described in Wizarat (1981). No previous studies have developed productivity measures on a district basis for Pakistani agriculture.[2] The only prior study estimating the contribution of crop research programs to productivity change in Pakistan's agriculture is the Nagy (1990) study. This volume reports a new analysis of the contribution of agricultural research to crop productivity growth and to aggregate productivity growth.

Chapter I presents an overview of the research institutions in Pakistan and documents changes in the system associated with the development of the Pakistan Agricultural Research Council (PARC). Characteristics of the system are discussed, and some of these are subjected to further analysis in later chapters.

Chapter II develops and reports both Partial Factor Productivity (PFP) and Total Factor Productivity (TFP) indexes for Pakistani agriculture. These indexes are computed for most districts for the 1955-56 to 1985-86 period. This chapter also reports a comparison of TFP changes in the Indian state of Punjab and the Pakistani provinces, utilizing comparable computational methods and data.

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[1] See Evenson and Pray (1990) for a summary.

[2] Wizarat (1981) reports a national series.

Chapter III reports a statistical analysis of the determinants of TFP change at the district level. This analysis is comparable to studies in other countries usually referred to as TFP decomposition studies. The analysis estimates the contribution of research and infrastructure investments to productivity growth.

The results of a statistical analysis of PFP indexes (yields) for several crops are reported in Chapter IV. This analysis is more complex than the TFP analysis and requires a more complex methodology. Crop specific analysis provides additional insight into the role of research programs because differences between crop research programs can be observed.

The final chapter analyzes the economic implications of the parameter estimates. Estimates of benefits, based on total (i.e., producer plus consumer) surplus, are utilized to compute marginal internal rates of return (MIRRs) to investment in research. International comparisons with other studies are also provided.

The findings of this study are summarized in the following table which reports the estimated MIRRs to investment in agricultural research in Pakistan. These returns to investment are, in general, extraordinarily high. The PFP decomposition estimates computed in Chapter IV allow us to compare returns for different commodity research programs. Of the major commodity research programs in Pakistan, significant research impacts and high returns were estimated for all programs except sugarcane. We were unable to address the question of returns to livestock research.

We were, however, able to obtain estimated impacts and rates of return for both the highly applied commodity-focused research in the system and the more general research, which included more basic research and some livestock research. These estimates are made in Chapter III and summarized in Chapter IV and in Table 0. Computations were made including and excluding the direct contribution of high-yielding varieties (HYVs). We note that the inclusion of the HYV effects did result in higher returns to investment. However, it is pertinent to note that even when these are excluded, returns to investment in Pakistani agricultural research have been very high.

Table 0: Estimated Marginal Internal Rates of Return to Agricultural Research in Pakistan (1956-86)

SOURCE	METHODOLOGY	COVERAGE	ESTIMATED MIRR
Chapter III	TFP decomposition	Applied research (excl HYV)	0.57-0.63
Chapter III	TFP decomposition	Applied research (incl HYV)	0.82
Chapter III	TFP decomposition	General research (excl HYV)	0.46
Chapter III	TFP decomposition	General research (incl HYV)	0.56
Chapter III	TFP decomposition	All agricultural research	0.57-0.65
Chapter IV	PFP decomposition	Wheat research	0.76
Chapter IV	PFP decomposition	Rice research	0.84-0.89
Chapter IV	PFP decomposition	Maize research	0.40
Chapter IV	PFP decomposition	Bajra research	0.44
Chapter IV	PFP decomposition	Jowar research	0.52
Chapter IV	PFP decomposition	All cereals research	0.81-0.84
Chapter IV	PFP decomposition	Cotton research	1.02
Chapter IV	PFP decomposition	Sugarcane research	N/A

In Chapter V these estimates are compared with approximately 75 other estimates obtained from studies of other countries using similar methodologies. The Pakistani estimates compare favorably, not only against an objective standard for returns to investment, but with results obtained in other countries as well.

This study thus reaches the conclusion, which has strong statistical support, that Pakistan's agricultural research system has been productive. It has produced high rates of return to investment. It has produced economic growth in agriculture at low cost and that growth has been vital to Pakistan with its rapidly growing population. There is little doubt that investments in agricultural research programs have been among the most productive investments in Pakistan over the past 40 years.

It does not follow, however, that the research system has been as productive as it could have been. This study has noted problems with *congruence*, particularly with respect to rice.[3] Currently there are serious problems with the provision of operational support to allow scientists to get their work done. The basic research support system is very weak.

[3] Congruence refers to the correspondence between the crop mix and research emphasis.

Furthermore, it does not follow that the system has solved all or even some of Pakistan's major problems. Soil salinity has probably worsened. Our data show severe problems in the North West Frontier Province (NWFP) which must be addressed. It is important to note, however, that agricultural research programs cannot solve all problems. Research programs are designed to develop technology which enables farmers to achieve greater productivity and enables the economy to get more production from the resources at hand.

This they have done in Pakistan. It is clear that Pakistan has under-invested in agricultural research. Among the alternative routes by which an economy can raise output, such as expanding the area under cultivation, increasing irrigation levels, and applying fertilizer more intensively, research as been a bargain in terms of growth achieved relative to cost. For an economy like Pakistan's, the biggest bargains in the process of achieving economic growth are probably its agricultural scientists. Not only are they productive, but they are low cost.[4]

Pakistan faces challenges in the future. Its population will double in the next few years. It must double food production merely to maintain per capita food production. It has brought most cultivable land under cultivation now. If Pakistan is to meet this challenge, it must realize gains in productivity. To do this, it must expand and strengthen its agricultural research system as well as its extension and farmer education programs. The evidence for high returns to agricultural research from this study is strong. Research contributes to productivity. Numerous other studies reveal the same conclusions. Agricultural research programs will have to play a larger role in the future. Countries such as Pakistan cannot afford to continue to underinvest in their research systems and to provide inadequate support to agricultural scientists.

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[4] This study has documented the fact that the ratio of the real cost of supporting a scientist relative to the costs of irrigation equipment, fertilizer, etc., is very low in Pakistan.

Chapter I

AGRICULTURAL RESEARCH: INSTITUTIONAL DEVELOPMENT IN PAKISTAN

During the past four decades of planned economic development in Pakistan, significant structural changes have taken place in the economy. Nevertheless, agriculture remains the largest sector of the economy in terms of output, employment, and contribution to exports. As in most other developing countries, the share of agriculture in GDP has declined over recent years, from 32% in 1975-76 to 22% in 1988-89, indicating higher growth rates in other sectors of the economy. Many of these sectors, however, depend directly or indirectly on agriculture.

Pakistan's current population of 103.8 million is increasing at the rate of approximately 3% per annum and will reach almost 140 million by the turn of this century. Thus, to sustain this population at current levels of consumption, agricultural production will have to be increased by at least 40% over the next 10 years. In fact, even higher production will be required to meet the growing needs of the high income groups of society, of industries, and of export markets. This is by no means an easy task because the country has effectively reached the extensive margin of cultivation on available land. Existing agricultural land resources, apart from being afflicted with desertification, soil erosion, salinization, and waterlogging, are being rapidly diverted to non-agricultural uses such as residential accommodation, industrial estates, and recreation parks. On a per capita basis, cropped area and area under food grains have actually decreased by 13% and 9% respectively during the last decade.

Agricultural policy in the 1960s was directed primarily towards increasing agricultural production through the expanded use of subsidized inputs, namely fertilizer, pesticides, and tubewells. In the middle of the decade, high yielding varieties of rice and wheat became available from international research institutions such as the International Rice Research Institute (IRRI) and Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT). During the later part of the 1970s and the early 1980s, growth in agriculture resulted largely from productivity growth based on agricultural research programs and the modification of basic agricultural policies, such as increased availability of agricultural credit and irrigation facilities as well as pricing and procurement policies.

Growth in agricultural production stems mainly from two sources: increased use of inputs such as land, fertilizer, and water; and productivity growth or growth in product per unit of input. In countries such as Pakistan where the options for low-cost expansion of cropped area have largely been exhausted, most output growth typically comes from the second source - productivity growth.

Productivity growth is not realized spontaneously or without directed investment. It requires investment in: research programs to produce new and improve existing technology; in extension programs to facilitate the adoption and use of improved technology; in farmer education to facilitate their response to technological opportunities; and in infrastructure to create more efficient markets for products and factors. In addition, it requires an economic environment conducive to appropriate investments in capital by farmers. In this introductory chapter we review the development of the agricultural research system in Pakistan. In section 1.1 we review existing institutions while in section 1.2, quantitative indicators of investment and manpower are developed and comparisons with other countries are made. In section 1.3, we report data that indicate the qualitative dimensions of the program. Section 1.4 reports further detailed data from the MART-WINROCK survey undertaken as part of this study. Section 1.5 reports extension and schooling data. The final section summarizes the state of research institutions in Pakistan.

1.1 Institutional Development of the Agricultural Research System in Pakistan

Since 1920, agriculture has been a responsibility that was constitutionally assigned to the provincial governments, and agricultural research, education, and extension were carried out almost exclusively by the provincial governments. In the mid 1920s, the government of British India realized the need for a central body that would ensure coordination of provincial scientific research. The Imperial Council of Agricultural Research (ICAR) was thus established in 1929. The ICAR, which established a number of world famous institutions in India, went through several transformations in its mandate, structure, and organization in the 1930s and 1940s. Unfortunately all of ICAR's central research institutions were located in India at the time of partition. Not a single central institute of ICAR was located in the territories that constituted Pakistan. The only research establishments in Pakistan at the time of independence were the provincial research stations which had been established in the undivided India to undertake applied and adaptive research on certain agricultural commodities. The development of a centralized research system to cover the major agro-ecological regions and important commodities became the responsibility of the new government.

After gaining independence in 1947, Pakistan established the Food and Agriculture Council, but it had little power and few funds. The Agriculture Research Council (ARC) was formed in the mid 1960s. In 1978, ARC was reconstituted as an autonomous body at the federal level and renamed the Pakistan Agricultural Research Council (PARC). PARC was given a mandate to work in close coordination with the Ministry of Food and Agriculture, provincial agriculture departments, agricultural research institutes, and agricultural universities.

1.1.1 Pakistan Agricultural Research Council (PARC)

With its revised charter, PARC now has the authority to, *inter alia*, promote and coordinate agricultural research in the country. In addition, PARC also maintains its own research centers: the National Agricultural Research Center (NARC), Islamabad; the Arid Zone Research Institute (AZRI), Quetta; the Crop Diseases Research Institute (CDRI), Islamabad; and the Pesticides Laboratories and Vertebrate Pest Control Laboratory (VPCL), Karachi.

1.1.2 Other Federal Institutions

Although PARC has been established as an apex body in agricultural research, it is not the only federal institution that conducts research in the field of agriculture. Research on land reclamation and water management is conducted by the Water and Power Development Authority (WAPDA). The Soil Survey Department conducts soil surveys. The Nuclear Institutes for Agriculture conduct research on various aspects of agriculture. The Pakistan Central Cotton Committee and the Pakistan Tobacco Board focus on cotton and tobacco.

A number of other federally funded research institutes conduct research on agricultural issues. They include: the Pakistan Council of Scientific and Industrial Research (PCSIR); the Irrigation Drainage, and Flood Control Research Council (now the Pakistan Council of Research in Water Resources); the Leather Board; the Pakistan Science Foundation (PSF); the Zoological Survey Department; and the Directorate of Marine Fisheries.

All these federal institutions are supervised by various ministries/divisions and their research programs and projects are not coordinated by any one organization. PARC supports some research in most of these institutions through cooperative research programs. However, the annual work plans and research programs of these institutions are not dovetailed into the total research system of the country, and their individual research efforts are often isolated.

1.1.3 Provincial Agricultural Research Institutions

Each province has an agricultural research institute with sub-stations for crops. There are a number of commodity-oriented institutes which are part of the main provincial institute. Punjab, Sind, and NWFP have agricultural universities, all of which are involved in limited agricultural research programs. Research on crops is conducted primarily by the provincial Departments of Agriculture, whereas research on livestock and fisheries is the responsibility of the provincial Departments of Livestock, Fisheries, Poultry and Dairy Development. Some research on forestry is carried out by the provincial Forest Departments. Research on land and water use is carried out by the provincial Departments of Agriculture and Irrigation and by the universities.

1.1.3.1 Punjab

The Ayub Agricultural Research Institute (AARI) evolved in 1961 from the Punjab Agriculture College and Research Institute, which had been established in 1909. In 1962, the college was upgraded to university status and the institute was started on a new campus. The main institute is located at Faisalabad and there are 18 stations/substations at different locations in the province. Some commodity research stations are located in different ecological zones. The following sections have attained institute status: the Wheat Research Institute; the Vegetable Research Institute; the Sugarcane Research Institute; the Oilseed Research Institute; the Cotton Research Institute; the Plant Protection Research Institute; the Rice Research Institute; and the Maize and Millet Research Institute.

There are a number of other research institutions located in Punjab that are not governed by or affiliated with AARI. The Rapid Soil Fertility and Soil Testing Institute, Lahore, is administered by the provincial Department of Agriculture, although it is part of AARI. The Directorate of Land Reclamation, which conducts research on soil alkalinity and waterlogging, is controlled by the Punjab Irrigation Department. The Punjab Irrigation Research Institute serves the entire country for hydraulic model studies on large structures.

The research needs of the livestock industry are the joint responsibility of: the Livestock Production Research Institute; the Livestock Experiment Station at Qadirabad; and the Veterinary Research Institute. There are 16 livestock experiment stations and laboratories that do research on livestock production, poultry, and fisheries. The Agricultural Research Mechanization Institute (AMRI) at Multan conducts research on the design, development, and maintenance of agricultural machinery.

The University of Agriculture at Faisalabad (UAF) comprises six faculties, one division, and the College of Veterinary Sciences. It is supported by federal grants received through the University

Grants Commission (UGC). Traditionally it was administered by the Provincial Education Department. Recently it has been transferred to the Provincial Department of Agriculture in an attempt to strengthen the association between teaching, research, and extension, and to ensure that the students have adequate hands-on agricultural experience.

Within the total agricultural research system in Punjab, there is some dispersal of effort, not only among the provincial institutions but also between the federal and provincial institutions. There are, for instance, four agencies involved in cotton research in Punjab and five others elsewhere in Pakistan, with little or no coordination among their individual programs. A provincial Coordination Board exists under the chairmanship of the Vice-Chancellor of the UAF. The Board has 67 members and five executive directors who are in charge of agriculture, livestock, economics, engineering, and information and logistics. All research institutes are represented on the Board, including PARC. The Board has been given financial as well as planning authority. It monitors and evaluates research projects financed by the province.

1.1.3.2 Sind

The Agricultural Research Institute (ARI) at Tando Jam, which deals primarily with crops and allied disciplines, was established in 1926 at Sakrand. It was moved to Tando Jam in 1955. It encompasses eight sub-stations and five research farms. In addition, the province supports the Rice Research Institute at Dokri which was founded in 1938 as a general crop research station, but gradually shifted its focus to rice in response to changes in cropping patterns and an increase in the land area under rice. ARI was considerably expanded in 1977 and maintains linkages with PARC and the International Rice Research Institute in the Philippines.

The Silviculture Division of the Forest Department deals with all silvicultural problems that arise from managing forests and maintaining nurseries, carries out experiments with exotic as well as inland forest plants, and also collects data on growth and related studies.

There are four livestock experiment stations which carry out research and development on Red Sindhi cattle, Kundi buffaloes, and other breeds of cattle. The Poultry Research Institute at Karachi develops vaccines for the local poultry industry.

Sind Agriculture University at Tando Jam was established in 1977 by upgrading the College of Agriculture. The university is administered by the Sind Department of Education and has no direct links with the provincial Department of Agriculture or ARI except through the Provincial Coordination Board.

Agricultural research at the University of Karachi is supported by grants from a number of sources including the University Grants Commission, PARC, and the Pakistan Science Foundation (PSF). The Center of Excellence in Marine Biology is located at Karachi University and is funded by the federal government through the Ministry of Education. Some fisheries investigations are also conducted by the provincial Department of Fisheries.

1.1.3.3 North-West Frontier Province

The Agricultural Research Station at Tarnab was established in 1910, and a network of sub-stations was subsequently added in response to the needs of various agro-ecological zones. The station became an institute in 1962. More recently, some regional stations have been upgraded and some specialized institutes have been established: the Sugar Crops Research Institute at Mardan, for research on sugarcane and sugar beets; the Cereal Crops Research Institute for research into cereal crops; the Gram and Pulses Research Institute at Ahmed Wala (Kark); and the Fruits and Vegetable Research Institute at Mingora (Swat) with sub-stations at Abbottabad, Dhodial, and Batakundi.

The Veterinary Research Institute at Peshawar is mainly concerned with the production of sera and vaccines, and with providing timely diagnostic services to cut down losses from contagious and parasitic animal diseases. The NWFP University of Agriculture was recently created by upgrading the Faculty of Agriculture, University of Peshawar. The government has executed an agreement with the U.S. government for launching a project entitled: "Transmission and Integration of Provincial

Agricultural Research Network (TIPAN)". The main purpose of this project is to establish a unified system of agricultural research, education, and extension in the province. An agricultural research coordination board has also been set up recently to coordinate research in the province.

1.1.3.4 Baluchistan

This province has only one major agricultural research institute which is located at Sariab near Quetta. This institute was established in early 1960 as a research station and was elevated to institute status in 1970. It concentrates on horticultural crops, although research is also carried out on wheat and pulses. The Veterinary Research Institute (VRI) at Quetta, established in 1979, carries out research on animal diseases and produces vaccines. The Beef Production Center was established at Sibi in 1969. An agriculture college has also been founded recently. Prior to this, students from Baluchistan received formal training in agriculture at Sind Agriculture University.

The Arid Zone Research Institute (AZRI) of PARC is also located at Quetta. It has three sub-stations in other provinces, namely Umarkot in Sind, Bahawalpur in Punjab, and Dera Ismail Khan in NWFP. PARC also supports some research in ARI at Sariab and VRI at Quetta. An agricultural research coordination board has been established in Baluchistan, but has not yet started to function.

1.1.4 Role of the Federal Government

In Pakistan, six ministries have some responsibility for research impinging on agriculture. Relations between ministries and research organizations are shown in Table 1.1. In addition to the ministries, the Pakistan Atomic Energy Commission (PAEC), which reports directly to the President through the President's Secretariat, has three institutes devoted to the use of nuclear energy in agricultural research. The ministries are responsible for financing the institutes under their control and for the determination of research policy, priorities, and programs.

Table 1.1: Ministries and Their Responsibilities

Ministry	Responsibility
Ministry of Finance, Planning and Coordination	Aiding Provincial Departments of Agriculture and their research institutes.
Ministry of Science and Technology	Irrigation drainage and flood control. Maintains two scientific research foundations.
Ministry of Food, Agriculture, and Cooperatives	Direction of Pakistan Central Cotton Committee. Maintains Agricultural Research Division (ARD) with the PARC.
Ministry of Commerce	Pakistan Tobacco Board
Ministry of Water and Power	Water and Power Development Authority (WAPDA)
Ministry of Education	University Grants Commission support to agricultural universities.

1.1.5 Role of Provincial Departments

Constitutionally, agriculture is a provincial matter. That is to say, the provincial departments of agriculture are responsible for the implementation of national agricultural policies in all their manifestations. Specifically, they control: higher education relating to agriculture through the agricultural universities, except in Baluchistan which shares the facilities of the other provinces; agricultural research, through the provincial agricultural research institutes; and extension, through their extension departments. While provincial research is generated in and controlled by the provinces, not all requests for development funds for research from the federal government are routed through the Agricultural Research Division (ARD).

1.1.6 Role of Agricultural Universities

The universities can be divided into two categories, general and agricultural. General universities, which contain departments of basic sciences, also undertake research in specific areas relating to the broad field of agriculture. Their work is carried out using in-house funds, funds for cooperative programs from outside agencies such as the USDA (under the Public Law 480 (PL-480) program) and

PARC, or other donor funds. In addition, PARC has set up in these universities some units that carry out specific research in applied fields, such as nematology and vertebrate pest control at Karachi University. Agricultural universities contain facilities for teaching and undertake applied agricultural research according to the interests of their well trained staff. They receive grants from outside agencies and PARC, and staff members take part in programs coordinated by PARC.

1.1.7 Administrative Comparisons with Agricultural Research Systems in Other Countries

A study conducted by the International Services for National Agricultural Research (ISNAR) reports that there are a number of developing countries which have agricultural research as a central or federal responsibility, and have been able to minimize duplication and wastage of their scarce resources. In most of these countries, including Brazil, Indonesia, and Argentina, agricultural production is a provincial responsibility whereas scientific and technological research, including policy planning and coordination, comes under federal purview.

In India, the Indian Council for Agricultural Research (ICAR), as the central lead organization, is responsible for organizing, directing, coordinating, and promoting agricultural research. It operates more than 34 national agricultural research institutes, four bureaus, and six agricultural commodity research centers. ICAR also acts as the University Grants Commission (UGC) for 23 agricultural universities in India. The United States, in the Department of Agriculture (USDA), has one of the most extensive and vigorous federal agricultural research organizations in the world. It has central and regional research centers to tackle the problems of major agricultural commodities in cooperation with local scientists.

1.2 Investment in Agricultural Research

It has long been recognized in Pakistan and elsewhere that the private sector - even in the most capitalistic economies - does not provide sufficient incentives to develop technology for agricultural production. In highly developed economies, the private sector invests significant amounts in research and development to improve farm machinery, chemicals, and animal health products because there are large farm input markets, and because they can obtain Intellectual Property Rights (IPRs), such as patents or copyrights, for their inventions. However, even in these economies the private sector invests little in the biological improvement of crops and animals. In a country such as Pakistan, where input markets are small and IPR protection is weak, there is very little private sector R&D directed towards agriculture.[5]

The remedy for this situation in most countries has been the development of a public sector research system, as well as public sector education and extension programs. These systems have been supported by and located in different political units. Pakistan is typical of most countries in having provincial and federal research units, as well as having access to International Agricultural Research Center (IARC) resources. It is also typical of many countries in that the provincial (state) units were developed long before strong federal units were developed. In Pakistan, the PARC programs (including NARC), were not established until after considerable development of provincial research centers, especially in the Punjab. It is also typical for such systems not to develop information systems that enable a complete accounting to be made of research resources for the economy, by commodity and disciplinary focus, and by the skill and training level of the research staff. Pakistan is only now moving towards the development of a national research information system.

In compiling the data presented here, information from the current Management of Agricultural Research and Technology (MART) Directory Project, as well as from the previous directory compiled by the National Sciences Council (NSC) of Pakistan, has been utilized. In addition, experiment station reports and returns from a recently conducted survey have been used.[6]

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[5] See Evenson (1990).

[6] See Azam (1988).

1.2.1 Data Issues and Problems

Before turning to a data summary, it will be instructive to discuss some of the problems encountered in developing this data base. The most important concerns are: determining staffing levels; determining actual research expenditures; and achieving time consistency.

1.2.1.1 Distinguishing Between Researcher/Scientist and Technician/Assistant

In highly developed research systems, it is convenient to argue that status as a scientist, with few exceptions, requires the Ph.D. or equivalent degree. That standard cannot be applied to Pakistan or to similar systems where many, perhaps most, research programs are effectively managed by scientists with considerable experience, but not always with a Ph.D. or even a M.Sc. degree. An alternative criterion for identifying the critical research manpower stocks is to include as scientists those researchers who have full research project responsibility. This generally means a GS rating of 16 or above for public sector employees. For meaningful policy comparisons, it is also critical that a distinction be made between research scientists, technical assistants, and other field staff. The latter category is often so affected by local bureaucracy as to render total staff counts meaningless as indicators of research capacity.

A similar distinction should be made between the financial resources used to hire staff and the funds used for equipment and other support. This is useful to policy makers because research systems often drift into very inefficient factor proportions. For example, the budget share allocated to salaries is often large and leaves too few resources for conducting research. This particular problem is discussed further in section 1.3.

1.2.1.2 Isolating the True Research Component in Program Budgets

For institutions set up to conduct research as their primary objective, it is relatively easy to associate their budgets with research, and occasionally extension, programs. Thus for provincial research units such as the rice research station at Kala Shah Kaku, the identification of research activities is straight-forward.

For universities, where faculty are engaged in both research and teaching, the allocation decision is more complex. It is usually conceptually possible to identify the relative proportion of faculty time expended on research and technology, but often the appropriate data are not available. It is clearly a mistake to attribute the entire budget of the various provincial universities to research. We have attempted to include only the research unit budgets in our research data, plus 20% of the university budgets and staff. A better estimate of the proportion of university faculty time expended on research is called for.

The problem is more serious where research activities are only one of several activities of an institution, and often a minor one at that. The Livestock and Dairy Development Department of the Punjab, for example, engages in many activities, including some animal breeding and animal improvement research. The budget of this unit is large. Indeed, if one were to consider this breeding work as research, it would constitute the bulk of agricultural and livestock research in Pakistan. Thus it is critical that this budget be carefully examined and that a distinction between normal production work and actual research activity be made. The production of breeding herds is generally not research. Provincial budgets in Pakistan generally do not make such distinction and are thus of little value for research investigation.

1.2.1.3 Achieving Consistency Over Time

Research units may be combined at certain periods. New units may be created. Accounting procedures may change. For example, provincial budgets in Pakistan do not provide consistent accounting categories for development and non-development expenditures. Also, budget categories differ by province, and it appears that many non-research activities are included in research and extension categories.

These problems render provincial budgets even less useful as indicators of research activity. The PARC budget is also of limited usefulness in this respect because it covers only a proportion of the agricultural research activities in Pakistan, and this proportion varies over time. We have thus developed our budget and staff estimates from the following sources:

1.) The NSC Directory of Agricultural Scientists (1982),

2.) The NSC Directory of Agricultural Research Establishments in Pakistan (1982),

3.) Results of a PARC-MART survey of research institutions,

4.) Provincial data from the MART-ARM institutional data set, and

5.) Estimates of expenditure by year - for growth of R&D manpower and expenditure in Pakistan, Pakistan Council for Science and Technology (PCST), 1985.

1.2.2 A Summary of Research Investment

From these sources we have compiled three tables providing estimates of agricultural research manpower and expenditures in Pakistan. Table 1.2 summarizes research expenditures in current rupees (Rs) for crop, livestock, and irrigation research, by region for selected years. Our procedure for constructing Table 1.2 was to treat the 1978 data from the NSC Directory of Agricultural Research Establishments as the most comprehensive and complete available. We compiled both expenditure and staff data from this source. For years prior to 1975 we had two sources. For 1960 and 1970 expenditures, we used the comparative data in the PCST report "Growth in R&D Manpower and Expenditures". This source provides data for 1977-78, and although these differ slightly from the NSC data, we consider them to be reliable indexes of spending in one period relative to another. Accordingly we extended the 1978 NSC data backward to 1970 and 1960 using the PCST 1970/1978 and 1960/1970 ratios for the relevant categories. The NSC Directory of Agricultural Scientists (1982), which contains data for 1978, gave us a second source of staffing data. These data allowed us to compute the number of staff in previous years. The data indicate the years employed by the present and prior institution, and total years of research carried out. This data was checked against that from the PCST. We considered NSC Directory data to provide more accurate staffing estimates for earlier years.

Table 1.2: Agricultural Research Expenditures (Millions of Rupees)

	1950	1960	1970	1978	1988
CROP RESEARCH					
Federal	1.50	10.00	13.41	63.90	93.00
Punjab	0.33	2.19	8.41	73.40	285.00
Sind	0.27	1.79	6.93	25.10	117.00
NWFP	0.25	1.09	6.53	22.90	43.00
Baluchistan	-	-	0.68	5.40	15.00
Total	2.35	15.66	35.96	191.00	552.00
LIVESTOCK RESEARCH					
Federal	-	-	-	8.89	27.00
Punjab	-	0.90	3.46	15.49	39.00
Sind	-	-	-	7.60	32.00
NWFP	-	-	0.09	1.90	6.00
Baluchistan	-	-	-	0.10	1.00
Total	-	0.90	3.54	33.80	105.00
IRRIGATION RESEARCH					
Total	-	-	0.93	18.20	85.00
ALL RESEARCH					
Grand Total	2.35	16.56	43.98	243.00	743.00

To update the 1978 data we needed better data than currently are available. Budget data for PARC institutions are readily available. However, we have only partial data for other research institutions. For these we have a survey conducted in 1988 from which we attempted to update the 1978 NSC Directory data.[7]

The MART-WINROCK 1988 survey was sent to the 65 institutions included in the NSC Directory. Useable returns for 50 institutions were received. For several other institutions we obtained

[7] See Appendix A, Tables A.1 and A.2.

data from the MART-ARM survey of expenditures.[8] From these sources we were able to obtain reliable estimates of both research staff and expenditures for 1988 for most institutions. For those units for which data were not obtained, we assumed expenditure changes proportional to those for which we did have data.

Table 1.3: Agricultural Research Expenditures (Millions of 1988 Rupees)

	1950	1960	1970	1978	1988
CROP RESEARCH					
Federal	21.40	69.20	70.26	113.10	93.00
Punjab	4.71	15.08	44.07	130.57	285.00
Sind	3.85	13.14	36.31	44.43	117.00
NWFP	3.56	7.54	34.21	40.53	43.00
Baluchistan	-	-	3.56	9.56	15.00
Total	33.52	104.96	148.74	338.19	552.00
LIVESTOCK RESEARCH					
Federal	-	-	-	15.57	27.00
Punjab	-	6.23	18.13	27.42	39.00
Sind	-	-	-	13.45	32.00
NWFP	-	-	0.47	3.36	6.00
Baluchistan	-	-	-	0.17	1.00
Total	-	6.23	18.60	59.97	105.00
IRRIGATION RESEARCH					
Total	-	-	4.87	33.44	85.00
ALL RESEARCH					
Grand Total	33.52	111.19	172.21	431.60	743.00

Table 1.2 thus reports current expenditure data. Table 1.3 reports the same data in 1988 constant rupees, where the General Wholesale Price Index (WPI) has been used as the deflator. These data will be discussed further in section 1.3, but we will note at this point that, in spite of very substantial program efforts in the past decade, growth in real expenditures and in staff has not been rapid.

[8] The staff data reported in the ARM data at this point include total staff and thus are not useful as measures of research staff, though further compilation should correct this.

1.2.3 Research Intensities: International Comparisons

A comparative index widely used to assess relative investment levels is the *intensity* indicator. This is the ratio of investment in research to the value of the commodity or commodities where research is directed. Table 1.4 reports intensity indicators for Pakistan and for other regions.

Table 1.4: Research Expenditure Intensity Indicators

I. Total Agricultural Research Expenditures/Value of Agricultural Product					
YEAR	PAKISTAN	SOUTH ASIA	SOUTHEAST ASIA	LOW-INC DEVLPG	MID-INC DEVLPG
1960	0.0022	0.0012	0.0010	0.0015	0.0029
1970	0.0028	0.0019	0.0028	0.0027	0.0057
1978	0.0049	0.0043	0.0052	0.0050	0.0081
1988	0.0052	N/A	N/A	N/A	N/A

II. Research Spending on Commodity/Value of Commodity (1980)				
COMMODITIES	PAKISTAN	ASIA	ALL DEVLPG COUNTRIES	IARCs TOTAL
BAJRA	0.0081	N/A	N/A	N/A
JOWAR	0.0081	N/A	N/A	N/A
MAIZE	0.0080	0.0021	0.0025	N/A
COARSE CEREALS	0.0084	0.0021	0.0023	0.1100
RICE	0.0010	0.0021	0.0025	0.0700
WHEAT	0.0033	0.0032	0.0051	0.0400
SUGAR	0.0026	0.0013	0.0027	N/A
COTTON	0.0040	0.0017	0.0021	N/A
OTHER COMMODITIES	0.0081	N/A	N/A	N/A

Panel I reports the ratio of annual spending on research programs to the value of agricultural product for several periods for all research. Comparative data for South Asia, Southeast Asia, low-income developing, and middle-income developing countries are provided. In 1960, by this measure, Pakistan was more research intensive than other countries in South and Southeast Asia and other low-income developing countries. By 1970, the South Asian and low-income developing countries were on par with Pakistan. By 1978, all developing countries had expanded their research investments. Pakistan made major advances in the 1970s, but only modest increases in the 1980s. Today, with approximately 0.5% of agricultural product expended on research, Pakistan ranks a little below the level for low-income developing countries and is at about half of the level achieved by the middle-income developing countries.

Crop specific data (Panel II) show that Pakistan spends only half as much on rice as do most other countries. For wheat, its intensity is near the South Asian standard, but below the level for all developing countries. For maize, Pakistan may be spending more than most other developing economies. In general, Pakistan has a low level of congruence between its research programs and its commodity values.

1.3 Qualitative Indicators of Pakistani Agricultural Research

We now turn to qualitative indicators of the strength of Pakistan's research program. These data deal with the basic/applied mix of research in the system, and with staffing mixes and staffing support. Most of the data utilized in this section were collected from research institutions as part of the MART-WINROCK survey.

1.3.1 Basic and Applied Research

We can obtain indicators of the basic/applied mix of research from publications data. Table 1.5 reports ratios of basic to applied publications abstracted in the Commonwealth Agricultural Bureau (CAB) abstracting journals.[9] This source is quite comprehensive and comparisons among countries are reasonably valid. Ratios are reported for three periods, for both crop and animal research in 25 developing countries.

It is quite clear from this listing that the Pakistani system is on the applied end of the spectrum, as only three of the 25 countries had lower basic/applied crop research ratios. Pakistan was also well below the average for the 25 advanced developing countries and for all developing countries. For animal research, only five of the 25 countries had lower basic/applied ratios. Pakistan did have

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[9] Notes at the foot of the table indicate distinction between basic and applied research in terms of abstracting journal.

Table 1.5: Ratios of Basic to Applied Research

COUNTRY	CROP RESEARCH 1972-75	CROP RESEARCH 1976-79	CROP RESEARCH 1980-83	ANIMAL RESEARCH 1972-75	ANIMAL RESEARCH 1976-79	ANIMAL RESEARCH 1980-83
ARGENTINA	0.13	0.16	0.08	0.33	0.59	0.90
BRAZIL	0.18	0.19	0.17	0.66	0.97	0.91
CHILE	0.13	0.13	0.14	0.38	0.47	0.59
COLUMBIA	0.15	0.17	0.22	0.34	0.61	0.90
MEXICO	0.16	0.10	0.07	0.32	0.61	0.90
PERU	0.25	0.49	0.26	0.23	0.15	0.44
VENEZUELA	0.18	0.14	0.12	0.51	0.95	1.40
GHANA	0.12	0.07	0.12	0.25	0.48	0.53
KENYA	0.15	0.16	0.18	0.23	0.71	0.96
NIGERIA	0.14	0.22	0.19	0.32	0.59	0.64
SUDAN	0.12	0.04	0.13	0.58	0.53	0.60
TANZANIA	0.04	0.07	0.13	0.93	1.11	1.11
TUNISIA	0.09	0.05	0.07	0.57	1.18	2.10
UGANDA	0.10	0.06	0.23	0.29	0.97	1.79
EGYPT	0.14	0.16	0.16	0.30	0.41	0.50
SRI LANKA	0.08	0.09	0.09	0.33	0.36	0.26
INDIA	0.21	0.27	0.26	0.29	0.43	0.38
INDONESIA	0.05	0.10	0.08	0.64	0.92	0.43
SOUTH KOREA	0.14	0.15	0.19	0.58	0.43	0.61
MALAYSIA	0.22	0.21	0.17	1.07	0.61	0.51
PAKISTAN	**0.10**	**0.08**	**0.09**	**0.36**	**0.43**	**0.43**
PHILIPPINES	0.19	0.16	0.15	0.51	0.37	0.30
TAIWAN	0.17	0.29	0.27	0.76	0.42	0.30
THAILAND	0.17	0.16	0.18	1.37	1.97	2.68
TURKEY	0.41	0.40	0.28	0.47	0.73	0.50
25 DEVLP COUNTRIES	0.18	0.22	0.21	0.37	0.52	0.54
ALL DEVLP COUNTRIES	0.16	0.15	0.16	0.23	0.34	0.30

Ratios are based on counts of abstracted publications by class of journal defined by:

Basic Crop Journals	Helminthological Abstracts (B); Rev of Plant Pathology
Applied Crop Journals	Field Crop Abstracts; Herbage Abstracts; Horticultural Abstracts; Rev of Applied Entomology; Soils and Fertilizer Abstracts; Wood Abstracts
Basic Animal Journals	Helminthological Abstracts; Protozoologist Abstracts; Rev of Medical and Veterinary Mycology
Applied Animal Journals	Animal Breeding Abstracts; Dairy Science Abstracts; Nutrition Abstracts (Land and Feeding; Dev. of Applied Entomology (A); Vet Bulletin and Index Vet

somewhat higher ratios than the average for developing countries. Thus, Pakistan's research system is a highly applied system. It is not likely to be an exporter of scientific findings.

1.3.2 Staff Training Levels

Table 1.6 summarizes the training of agricultural scientists in Pakistan by the place and decade in which they obtained their B.Sc. degrees. It is clear that Pakistan did not send large numbers of students abroad for their B.Sc. in agricultural research, even in the British era and in the early post-independence period. Most of the degrees obtained abroad were from India. In the early period, the University of Agriculture at Lyallpur, now Faisalabad, was the largest producer of B.Sc. degrees.

The second panel of Table 1.6 shows that universities in the United States and the American University in Beirut were the primary foreign sources of M.Sc. degrees in agriculture. However, by the 1950s the Punjabi University of Agriculture was already a major producer of M.Sc. graduates. It was joined by the Agricultural Universities in the Sind and the NWFP in the 1960s and 1970s, as the U.S. graduated fewer Pakistanis with a M.Sc. degree in agriculture.

The United States has been the most important source of Ph.D. degrees, although universities in India, the Philippines, and Europe have also granted significant numbers. Ph.D. training began in Pakistan in the 1960s and has been quite substantial since the 1970s.

Table 1.7 shows the distribution of scientists by employing institution. The table shows that advanced degree holders were initially employed in universities, where they contributed to the training of B.Sc. and M.Sc. candidates, and later doctoral students.

Table 1.8 shows the distribution of training by discipline and by specialization. This table reveals that Pakistan's training strategy has been to upgrade skills in a wide spectrum of disciplines, rather than focusing on a few specializations.

Table 1.9 reports evidence on researcher productivity, where productivity is measured by the number of lifetime publications per scientist. Lifetime publications are categorized by the decade in which the B.Sc. was earned, and show the expected increase in publications for older scientists. The data shows that M.Sc. holders educated in the United States have been highly productive.

Table 1.6: Scientist Training in the Pakistan Agricultural Research System (by Place Degree Obtained)

Decade of B.Sc. Degree	Number with Degree	Punjab	Sind	NWFP	Baluchistan	USA	Australia	Beirut	India and Other
I. B.Sc. Holders (All Scientists)									
1940	111	86	5	1	0	0	0	0	19
1950	383	297	41	21	0	0	0	0	24
1960	950	545	206	186	0	2	0	0	11
1970	634	333	168	129	1	0	0	0	3
Total	2078	1261	420	337	1	2	0	0	57
II. M.Sc. Holders									
1940	35	14	1	2	1	5	0	2	10
1950	103	74	5	1	0	16	0	0	7
1960	508	239	150	43	0	37	2	28	9
1970	746	336	174	132	1	16	1	57	29
Total	1392	663	330	178	2	74	3	87	55
III. Ph.D. Holders									
1940	13	7	0	0	0	1	0	0	5
1950	9	0	0	0	0	5	0	0	4
1960	54	6	0	0	0	21	1	0	26
1970	106	19	9	1	0	31	4	0	42
Total	182	32	9	1	0	58	5	0	77

The regression estimates summarized in Table 1.9 are from a statistical analysis of lifetime publications correcting for age, experience, discipline, specialization, and place of employment. Estimates were obtained showing the corrected publication differentials between graduate and undergraduate training. The Ordinary Least Squares (OLS) results are generally in line with the group mean data, except that they show that after corrections are made, foreign Ph.D.s are less productive than holders of Pakistani Ph.D. degrees. In fact, obtaining an American Ph.D. gives no advantage over an American M.Sc.. The TOBIT estimate, which corrects for the fact that publications are censored at zero, shows essentially the same thing except that Pakistani M.Sc. holders are shown to be highly productive.

1.3.3 Support Per Scientist

Table 1.7: Scientist Employment in the Pakistan Agricultural Research System

Decade of B.Sc. Degree	Total	University Locations			Government Employment				
		Pun-jab	Sind	NWFP	Pun-jab	Sind	NWFP	Baluchistan	Federal
I. B.Sc. Holders									
1940	133	22	3	2	57	21	13	2	13
1950	383	86	12	6	159	43	35	6	36
1960	952	110	65	26	349	128	163	19	92
1970	638	45	42	10	211	108	125	24	73
Total	2107	264	122	44	776	300	336	51	214
II. M.Sc. Holders									
1940	18	3	1	0	1	7	2	0	4
1950	103	33	0	2	38	6	8	1	15
1960	511	134	37	18	129	87	43	16	47
1970	752	67	65	23	263	113	122	11	88
Total	1384	237	103	43	431	213	175	28	154
III. Ph.D. Holders									
1940	1	0	0	0	0	0	0	0	1
1950	9	3	2	0	2	0	0	0	2
1960	54	25	1	2	9	2	7	1	7
1970	106	49	13	4	8	8	5	3	16
Total	170	77	16	6	19	10	12	4	26

Table 1.10 reports expenditures per research staff member. These data show that expenditures per staff member rose after 1970 and have risen further during the 1980s at the provincial level, but have declined at the federal level. The International Agricultural Research Centers (IARCs) of the Consultative Group on International Agricultural Research (CGIAR) system conducted research on fewer than 20 commodities, but had a budget of $US 160 million (Rs 3.2 billion) during 1984. Per scientist expenditures in these institutions come to about $US 0.2 million, whereas per scientist expenditures in Pakistan are less than 4% of this amount.

In its 1987 report, a World Bank mission to Pakistan analyzed the recent costs and budgets for agricultural research and recommended an appropriate level of operational funding for Pakistan of $US 8000 per scientist. This level, however, is lower than the amount observed in a number of other countries examined by the mission. Average expenditures per scientist in Pakistan, covering salaries,

Table 1.8: Employment Distribution of Scientists by Discipline and Specialization in the Pakistan Agricultural Research System

Discipline	All	M.Sc.	Ph.D.
Engineering	47	29	4
Social Science	87	80	9
Veterinary Medicine	334	172	34
Chemistry	119	92	10
Crop Science	1176	806	95
Fisheries	41	33	5
Forestry	31	18	5
Physics	18	13	0
Soil Science	130	39	1
Technology	56	41	4
Other	51	39	5

Specialization	All	M.Sc.	Ph.D.
Agronomy	185	128	10
Animal Husbandry	163	96	11
Engineering	219	163	23
Entomology	1	0	0
Fisheries	33	25	5
Forestry	29	14	4
Horticulture	105	69	6
Industry	51	39	3
Statistics	38	34	0
Irrigation	29	17	1
Physics	12	11	0
Plant Breeding	352	235	35
Plant Pathology	132	100	15
Social Science	74	66	10
Soils	338	170	16
Veterinary Medicine	117	58	16
Wood	10	5	0
Chemistry	101	79	8
Biology	91	54	5

Table 1.9: Research Productivity Measures

Lifetime Publications per Scientist							
		M.Sc.			Ph.D.		
Decade of B.Sc.	B.Sc. Only	Pakistan	U.S.	Other	Pakistan	U.S.	Other
1940	8.35	24.77	51.61	16.36	37.67	43.00	30.80
1950	7.36	10.99	22.50	16.10	36.14	20.31	17.47
1960	1.39	5.28	12.70	6.48	13.67	16.77	21.97
1970	0.47	1.05	19.00	2.43	N/A	19.00	2.66
All	2.26	5.77	24.33	10.09	24.71	22.75	19.68

Regression Estimates of Productivity Differentials	OLS	TOBIT
Pakistani M.Sc. over B.Sc.	1.212 (1.37)	13.540 (8.19)
U.S. M.Sc. over Pakistani M.Sc.	10.110 (5.18)	9.496 (2.89)
Other Foreign M.Sc. over Pakistani M.Sc.	2.192 (1.33)	3.860 (1.90)
U.S. Ph.D. over B.Sc.	19.482 (4.60)	22.800 (3.62)
U.S. Ph.D. over Pakistani Ph.D.	-8.005 (2.53)	-8.862 (1.91)
Other Foreign Ph.D. over Pakistani Ph.D.	-4.079 (1.47)	-2.047 (0.50)

countries.[10]

1.3.4 Operational Support

The ratio of salaries to total funds is a commonly used measure of staff operational support. The World Bank calculated in 1980 that a ratio of about 7:3 of salaries to operational expenses was optimal for U.S. conditions. The National Commission on Agriculture in Pakistan (NCA) recommended that this ratio be 60:40 for Pakistan. At 1987-88 salary scales, this ratio for Pakistan was actually 84:16. This ratio is much too high. It shows that many individual research organizations at present do not have adequate operational support for research on numerous agricultural commodities.

[10] See also Appendix A, Table A.1.

Table 1.10: Agricultural Research Expenditures per Staff Member (Millions of Rupees)

PROVINCE	1960	1970	1978	1988
Federal	-	-	0.65	0.06
Punjab	0.08	0.07	0.12	0.19
Sind	0.35	0.21	0.13	0.48
NWFP	-	-	0.11	0.11
Baluchistan	-	-	0.12	0.18
TOTAL	0.35	0.13	0.16	0.15

operations, and development, are extremely low. Figure 1.1 reports comparative data for several

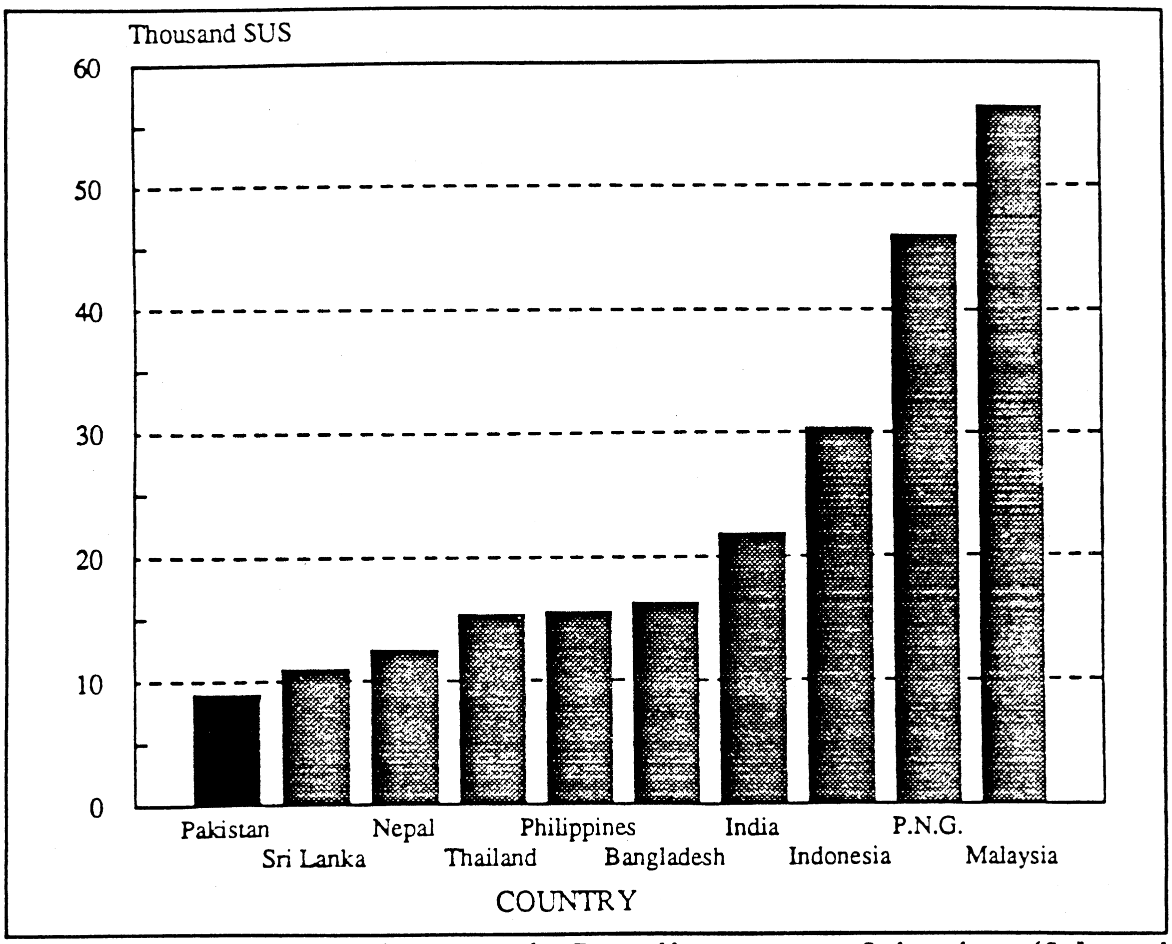

Figure 1.1: Agricultural Research Expenditures per Scientist (Selected Countries in Asia, 1980)

1.4 The MART-WINROCK Survey: Further Evidence

In order to further examine the state of funding, the ratio of salaries to operational expenses, and the availability of manpower in agricultural research, time series data were collected from 50 of the 65 agricultural research institutions in Pakistan. As Figure 1.2 shows, the total budget, development plus non-development, increased by 461% in nominal terms between 1978-79 and 1987-88. The increase in real terms was 189% percent.[11]

[11] See Appendix A, Table A.4.

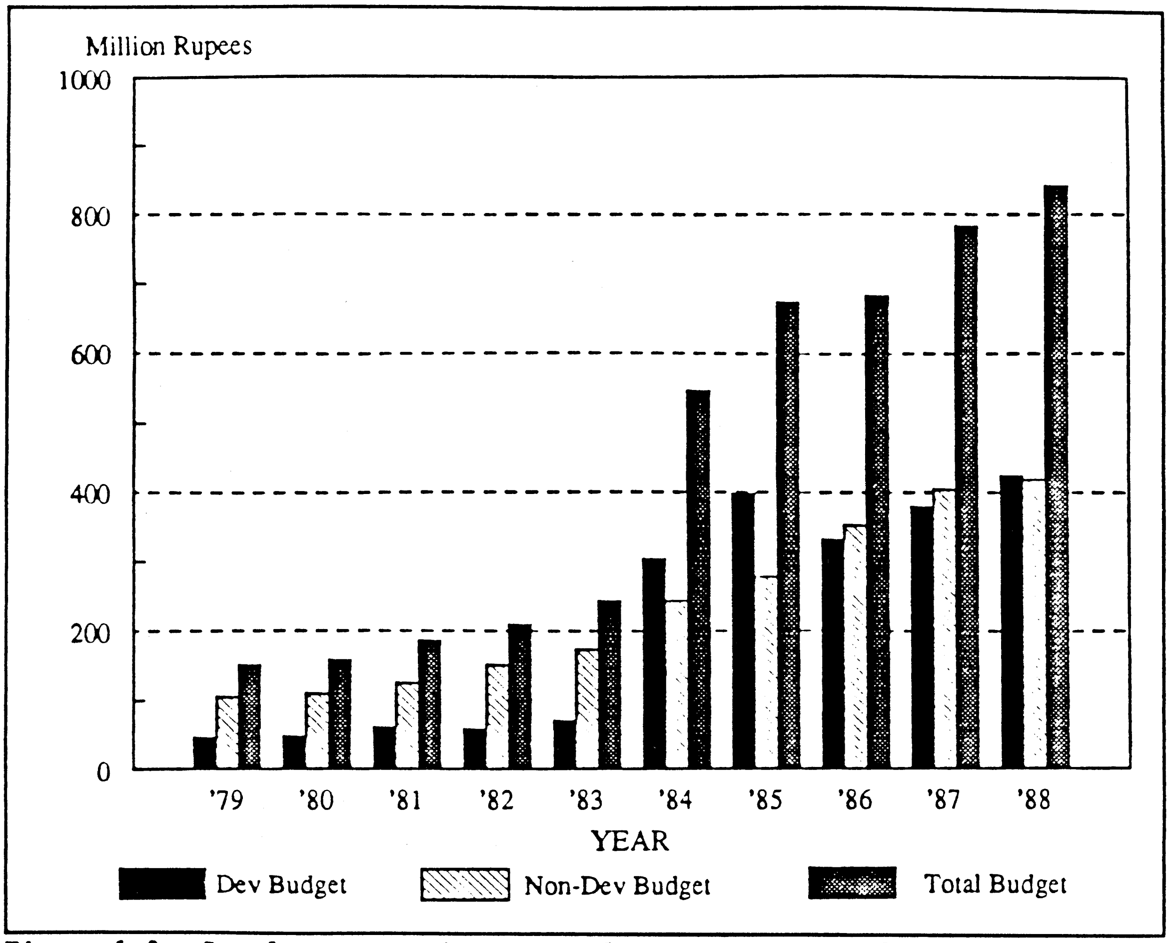

Figure 1.2: Development and Non-Development Budget of 50 Agricultural Research and Education Establishments

The non-development budget of these institutions increased by 301% in nominal terms during the decade 1987-88 to 1978-79. The increase in real terms was 108%.[12] Figure 1.3 reveals that salaries and allowances rose by 350% (134% in real terms), whereas operational expenses increased by only 150% (32% in real terms). The increase in operational expenses was less than the increase in prices of supplies and materials essential for research purposes. The ratio of salaries to operational expenses in 1987-88 was 84:16. This ratio means that the operational expenses need to be more than tripled, while holding salaries constant, in order to conform to the 60:40 proportion recommended by the NCA.

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[12] See Appendix A, Table A.5.

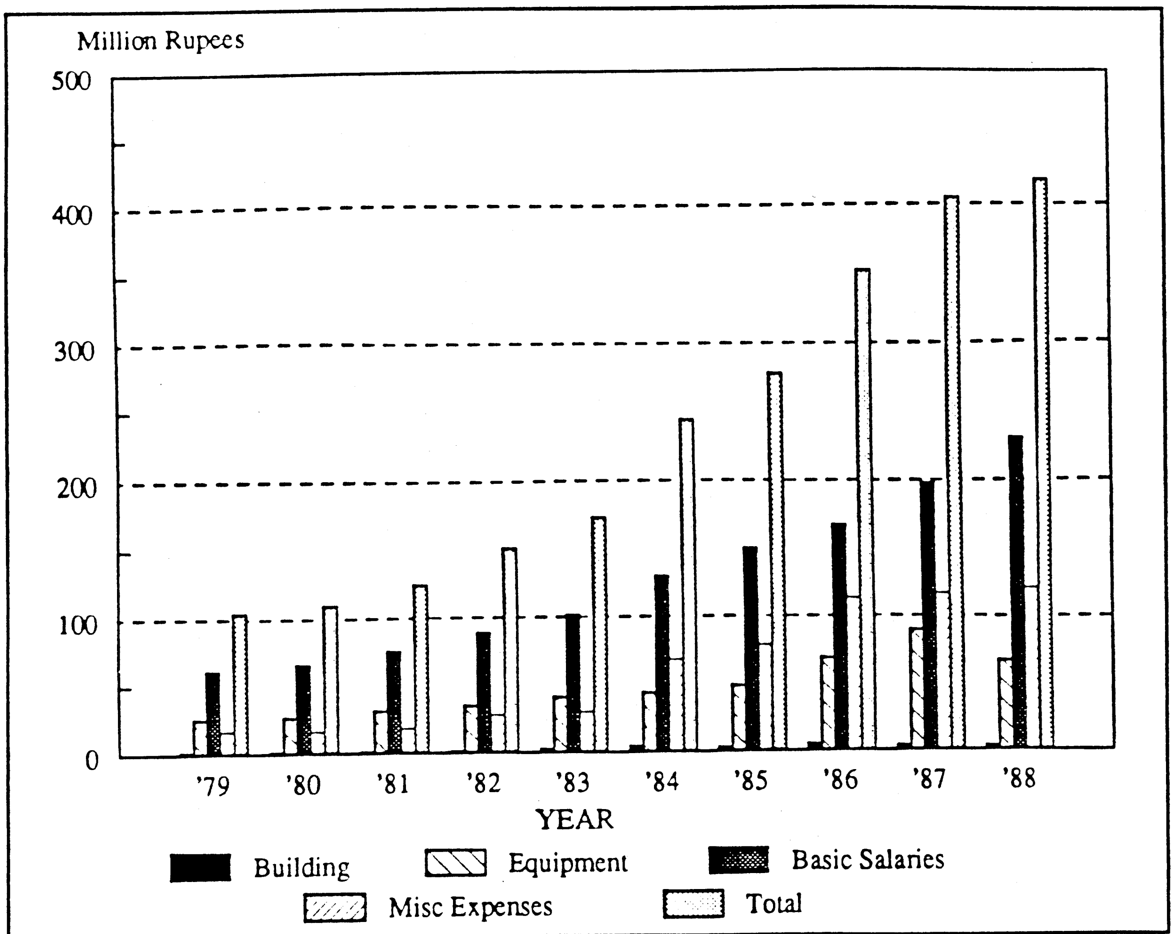

Figure 1.3: Non-Development Budget of 50 Agricultural Research and Education Establishments

Although the overall agricultural research budget increased by 460% (189% in real terms), Figure 1.4 shows that the trained manpower in these institutions increased only by 53%.[13] The total staffing position of the research organization is evident from Figure 1.5, which indicates that during 1978-79 about 87% of the sanctioned staff positions had been filled. This shortfall had been lessened slightly up to 1987-88, but actual staffing levels were still about 9% below sanctioned levels.

In order to further demonstrate the nature of the financial crises faced by individual research organizations/centers, an analysis of budget data from NARC was undertaken. This budget analysis

[13] See Appendix A, Tables A.3 and A.7.

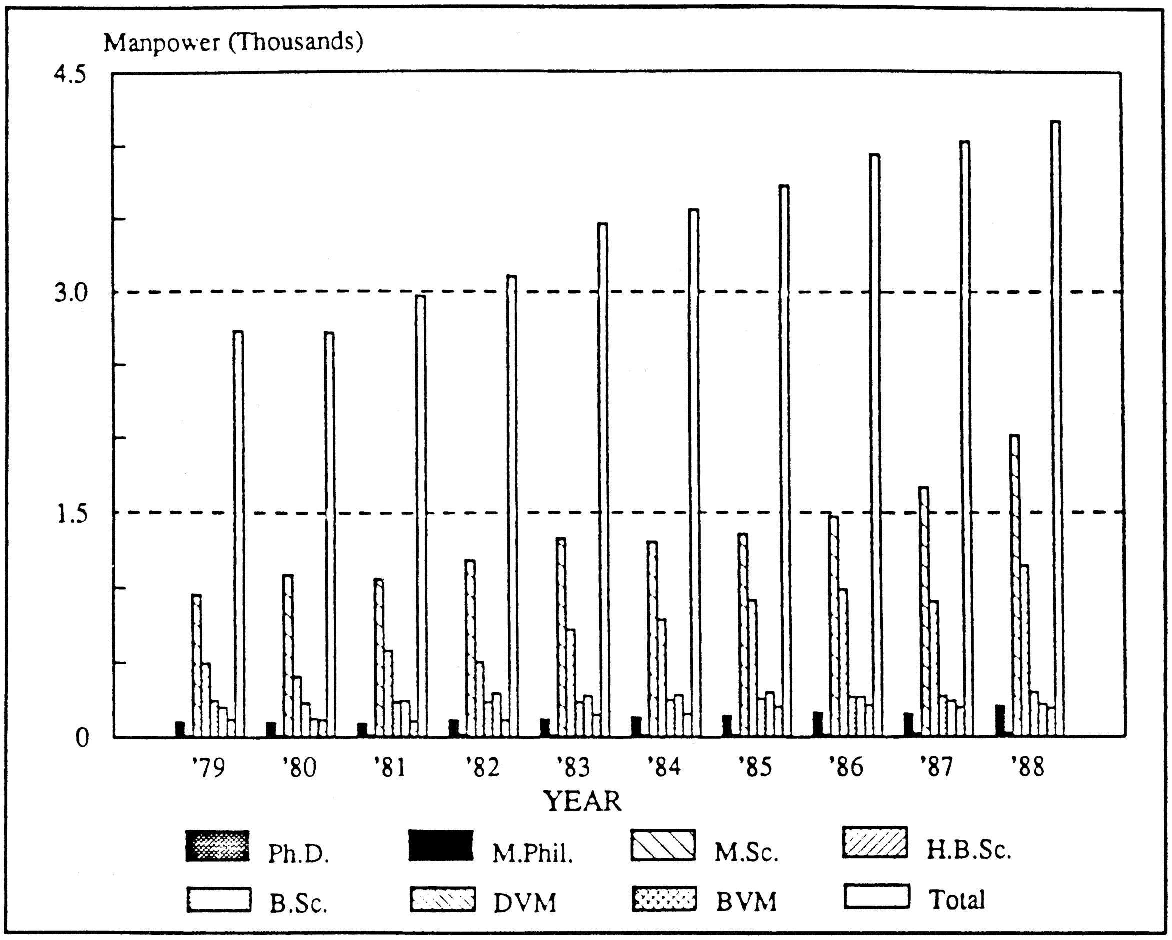

Figure 1.4: Trained Manpower in 50 Agricultural Research and Education Establishments

revealed that the ratio of salaries to operational funds was 55:45 during 1985-86, and steadily deteriorated to 58:42 in 1986-87, 66:34 in 1987-88, and 73:27 in 1988-89. It also shows that operational funds available to each scientist, Rs.84,000 during 1985-86, were about 40% below the World Bank recommended level of Rs 140,000. There has been a continuous decline in operational research funding per scientist. The funding level decreased from Rs 84,000 to Rs 42,000 per scientist in the four years from 1985-86 to 1988-89, whereas total staff costs, namely salaries, allowances, and other remunerative expenditures, increased by about 100% during the same period. The total NARC budget increased by about 36% over these four years.

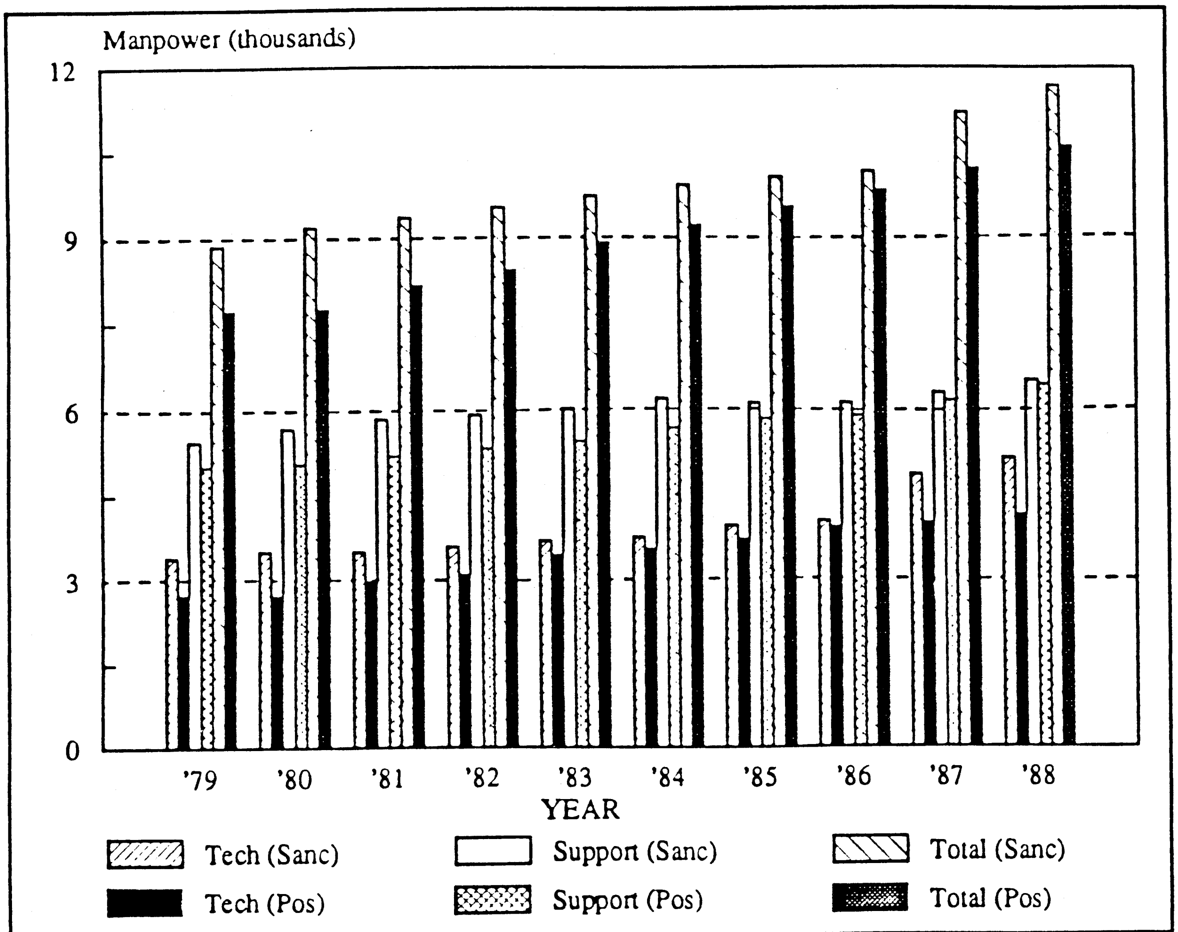

Figure 1.5: Sanctioned Staff Levels and Positions Filled in 50 Agricultural Research and Education Establishments

The state of selected commodity research programs, measured in terms of operational funding received, is shown in Figure 1.6.[14] An analysis of 36 research programs of NARC, covering wheat, rice, maize, and pulses, reveals that although the operational expenses of the wheat program were at the World Bank recommended level in 1985-86, the situation deteriorated and funding levels declined by 78%, 85%, and 87% respectively in the next three years.[15] While PARC has during the past decade developed a solid core of highly qualified and adequately trained scientists, their precious expertise can only be utilized if they are provided with adequate financial resources to carry out

[14] See also Appendix A, Table A.8.

[15] See Appendix A, Tables A.9 through A.12.

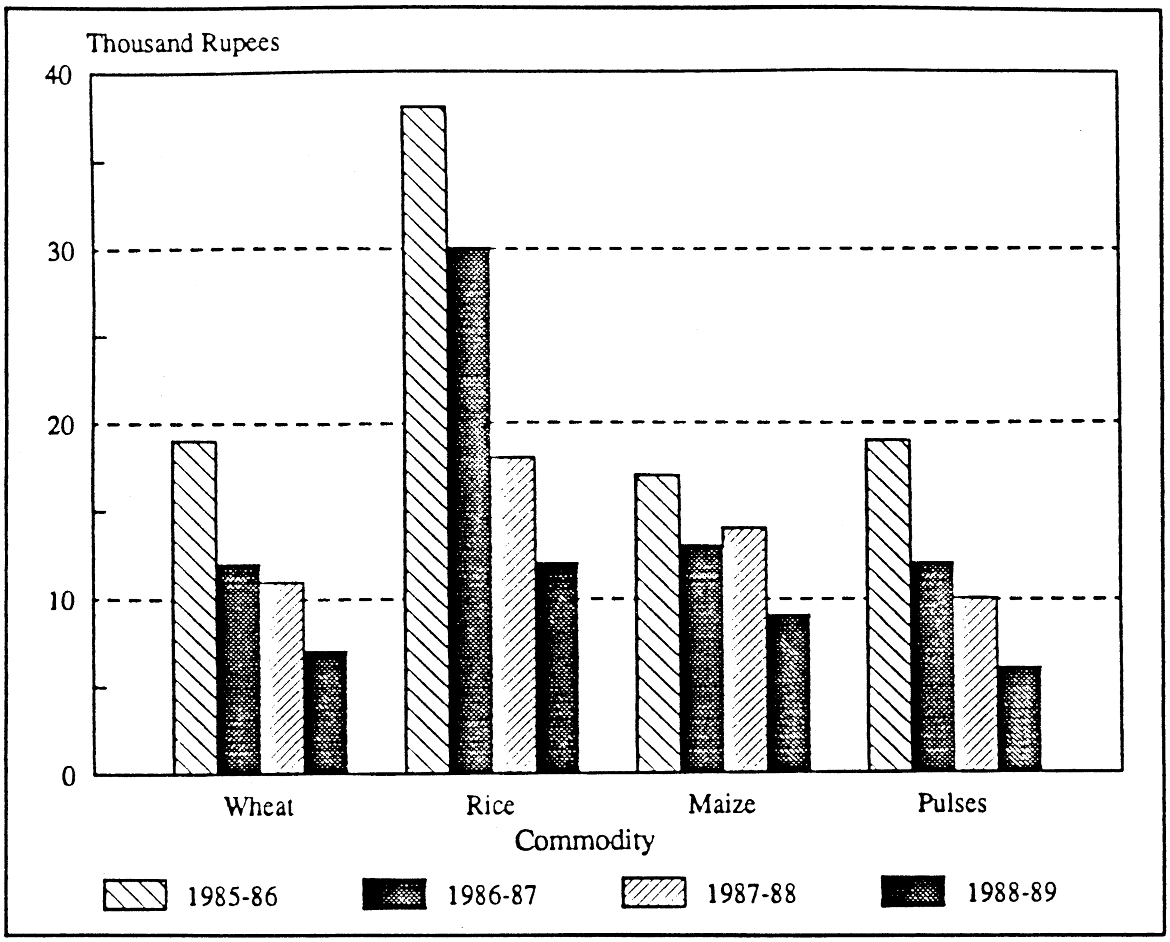

Figure 1.6: Operational Expenditure per Scientist for Selected Research Programs (NARC)

research of vital national importance.

1.5 Extension, Schooling, and Infrastructure

1.5.1 Extension

Expenditure data on agricultural extension by province as summarized from provincial budget books are presented in Table 1.11. This table shows that expenditures on agricultural extension have increased considerably but data are inadequate for further analysis.

1.5.2 Schooling

Table 1.11: Provincial Expenditures on Agricultural Extension (Millions of Rupees)

YEAR	PUNJAB	SIND	NWFP	TOTAL
1980-81	30.6	17.6	22.7	70.9
1981-82	32.8	18.4	34.2	85.4
1982-83	43.5	20.9	34.4	98.8
1983-84	56.1	22.2	122.1	200.4
1984-85	74.9	25.5	193.4	293.8
1985-86	117.6	27.5	198.5	343.3
1986-87	134.1	28.8	199.5	362.4
1987-88	265.5	29.0	215.3	509.8

Source: Compiled from provincial budget books.

In Pakistan the rural literacy rate is only 17%. Table 1.12 shows the literacy ratios of the population by gender, region, and urban/rural areas during 1972 and 1981. It is interesting to note that while the literacy rate increased in the rural areas of Punjab and NWFP by 5.3% and 2.2% respectively, it has declined in rural areas of Sind Province by 2%. The literacy rate in rural Sind declined more in the male than in the female population.

1.6 Summary

Pakistan was faced with a difficult institutional challenge after independence. It inherited little research capacity from its colonial past. It has, on the whole, responded quite effectively to this challenge. It has built and strengthened a large number of research institutions, most of which have been developed as part of the provincial systems. Federal coordination and national research centers are of recent origin.

Quantitative investment indicators show that Pakistan has expanded its system approximately to the level of most other low-income developing countries. It now spends a little over 0.5% of its agricultural product on research. This, however, is well below the 0.8-1.0% standard that advanced developing countries have achieved in recent years.

Table 1.12: Literacy Ratios by Region, Gender, and Urban/Rural Areas, 1972 and 1981 Census (Percentages)

	RURAL		URBAN		TOTAL	
	1972	1981	1972	1981	1972	1981
PUNJAB						
Male	22.9	29.6	47.8	55.2	29.1	36.8
Female	5.2	9.4	28.0	36.7	10.7	16.8
Both	14.7	20.0	38.9	46.7	20.7	27.4
SIND						
Male	27.5	24.5	54.5	57.8	39.1	39.7
Female	5.8	5.2	38.4	42.2	19.2	21.6
Both	17.6	15.6	47.4	50.8	30.2	31.5
NWFP						
Male	19.0	21.7	44.7	47.0	23.1	25.9
Female	2.2	3.8	19.9	21.9	4.7	6.5
Both	11.0	13.2	33.7	35.8	14.5	16.7
PAKISTAN						
Male	22.6	26.2	49.9	55.3	30.2	35.0
Female	4.7	7.3	30.9	37.3	11.6	16.0
Both	14.3	17.3	41.5	47.1	21.7	26.2

Pakistan's system still exhibits several weaknesses that must be addressed. The most immediate problem is the unhealthy balance between staff funding and operational support. This is a problem that is widespread in the developing world and is not specific to Pakistan. It is also relatively easy to remedy.

Pakistan's research system also exhibits relatively poor congruence in its commodity orientation. The most obvious manifestation of this is that it spends far too little on rice research relative to the economic importance of this commodity. Further analysis of the mismatch between the economic importance of commodities and research emphasis is clearly called for. Again, it should be noted that Pakistan is not alone in having this problem.

Pakistan's research system is highly applied, particularly in crop research. India, for example, has a ratio of basic research to applied research that is more than twice that of Pakistan. This is consistent with the fact that the proportion of Pakistani scientists holding Ph.D. degrees is rather low.

Pakistan also suffers from an inadequate database on research programs, not just in PARC institutions, which hampers effective management of the system.

Chapter II.

CROP PRODUCTION AND PRODUCTIVITY IN PAKISTAN

Agricultural production is constrained by the skills of farmers, by technology available to the farmer, and by infrastructure in the form of roads, communication facilities, and marketing and processing facilities. When these constraints are binding and fixed, it is possible to characterize production in any period in terms of: production or transformation functions; or the *dual* maximized profits function. When these constraints are binding and do not change over time, it is also possible to express changes in production as a simple function of changes in quantities of factors (or of changes in prices).

However, when the technology or infrastructure available to farmers changes, as it is expected to as a result of research and extension programs, the simple expressions for changes in production no longer hold. The analyst essentially has two choices in measuring and analyzing such changes. The first option is to engage in a two-stage procedure. In the first stage, Total Factor Productivity (TFP) or Partial Factor Productivity (PFP) measures are computed for the relevant units under study, for example a farm or an aggregate of farms in a particular time period. This essentially divides the change in production into two parts. One part is the output change predicted by changes in factor quantities (or prices), computed as though technology and infrastructure had not changed. The second part is the residual TFP (PFP) part and is attributable to changes in technology and infrastructure.

In the second stage of this analysis, the TFP (PFP) part is then subjected to a statistical decomposition analysis in which TFP indexes are regressed on variables that are designed to measure the flow of new technology or infrastructure that is occurring over the periods observed. This two stage approach is the technique used in Chapters III and IV.

The second choice open to the analyst is to incorporate the variables measuring technology and infrastructure directly into the production or transformation functions, and/or the dual profits function systems. This choice can be described as the *meta* function approach because it specifically attempts to characterize the technology and infrastructure environment as part of the production environment.[16] This approach will not be pursued in this study.

In this chapter, TFP and PFP measures are defined and measured at the district level in Pakistan. Section 2.1 discusses methods. Section 2.2 reports PFP indexes by state for Pakistani agriculture. Section 2.3 reports TFP indexes. Section 2.4 develops a comparison of TFP growth in the Indian Punjab with TFP growth in Pakistan.

2.1 Measurement Methodology

There are two basic procedures for deriving Total Factor Productivity (TFP) change indexes: the accounting and the production (or transformation) function approaches. Under the accounting procedure, revenues are assumed to equal expenditures, but no knowledge of the production function is presumed. All of the early productivity measures for the aggregate U.S. economy were of this type.[17] In the production (or transformation) function approach, the producing unit under analysis is assumed to transform inputs into output subject to a production technology. For either approach, index numbers must be used to aggregate quantities into output and input indexes, and a specific index number formula is associated with a specific form of the production function. For example, the Laspeyres index number is an *exact* index for the Leontief fixed-coefficient production (or transformation) function, and the Geometric function index is exact for the Cobb-Douglas production function. However, when these indexes are *chained* and weights are allowed to change from period

[16] The conventional analysis treats technology and infrastructure as fixed and given.

[17] See Kendrick (1962).

to period, the Divisia index or the Fisher-Chained index are good approximations for any production function form.

2.1.1 The Accounting Approach to TFP Measurement

The accounting approach is based on the proposition that, when all factors are properly priced, receipts or income for a firm equal its expenditures. Assume an economic sector that is in long-run equilibrium. Firms may be minimizing costs and maximizing profits, but they need not be. They need not even be technically efficient. In equilibrium, firms will not be making economic profits because, if such profits existed, other firms would enter until profits were eliminated. Thus, equation (2.1) holds:

$$\sum_i P_i Y_i = \sum_j R_j X_j, \tag{2.1}$$

where the Y_i are outputs with prices P_i, and the X_i are inputs with prices R_i. Quasi-fixed factors, such as land or buildings, are treated as having a rental or service price.

Now differentiating (2.1) totally with respect to time, t, we have:

$$\sum_i Y_i \frac{\partial P_i}{\partial t} dt + \sum_i P_i \frac{\partial Y_i}{\partial t} dt = \sum_j X_j \frac{\partial R_j}{\partial t} dt + \sum_j R_j \frac{\partial X_j}{\partial t} dt. \tag{2.2}$$

This expression is exact for infinitely small changes.[18] Now, divide the left-hand side of (2.2) by $\Sigma P_i Y_i$ and the right-hand side by $\Sigma R_i X_i$, since these sums are equal, and multiply through the equation by unity: the first term by P_i/P_i; the second by Y_i/Y_i; the third by R_i/R_i; and the fourth by X_i/X_i. Define the output revenue share of the ith output by $S_i = Y_i P_i / \Sigma P_i Y_i$, and the factor cost share of the jth input as $C_i = X_i R_i / \Sigma X_i R_i$. Finally, we shall define the rate of change of a variable, X_i, by:

Transforming equation (2.2), we then obtain:

[18] For discrete or finite changes index number problems arise. This issue is dealt with below.

$$X_j^{\bullet} = \frac{1}{X_j}\frac{\partial X_j}{\partial t}dt.$$

$$\sum_i S_i P_i^{\bullet} + \sum_i S_i Y_i^{\bullet} = P^{\bullet} + Y^{\bullet} = \sum_j C_j R_j^{\bullet} + \sum_j C_j X_j^{\bullet} = R^{\bullet} + X^{\bullet}, \tag{2.3}$$

where P^{*}, Y^{*}, R^{*}, and X^{*} are rates of change of aggregated output prices, output quantities, factor prices, and factor quantities respectively. The rate of change in total factor productivity, T^{*}, can then be determined from:

$$T^{\bullet} = Y^{\bullet} - X^{\bullet} = R^{\bullet} - P^{\bullet}. \tag{2.4}$$

This is the difference between the rate of growth of the index of output and the index of inputs, or between the rate of growth of input prices and output prices. The motivation for this residual definition is that T^{*} measures gains made possible by efficiency improvements. The following interpretation of these gains can be given:

(a) If all inputs are unchanged (i.e., $X^{*} = 0$), then $T^{*} = Y^{*}$, or total factor productivity is identical to the increase in output (or the output index) achievable at constant input levels.

(b) If all outputs remain unchanged, (i.e., $Y^{*} = 0$), then $T^{*} = -X^{*}$, the rate of reduction in input usage for given output levels.

(c) If both inputs and outputs change, then $T^{*} = Y^{*} - X^{*}$ is the increase in total factor productivity. Note that the change in the output/input ratio (or factor productivity) for single factors is: $Y^{*} - X_j^{*}$, where X_j^{*} is the jth input. Thus, the rate of productivity growth is the rate of change in the ratio of outputs to inputs, or in the ratio of an output index to an input index.

(d) If all output prices are fixed, which might occur if all goods are traded internationally at fixed world prices or if we consider an individual firm in a large market, then $T^{*} = R^{*}$. Total factor productivity growth equals the rate of increase in factor prices or factor incomes made possible by efficiency gains.

(e) If all input prices are constant, (i.e., $R^{*} = 0$), which might occur when all inputs are traded internationally but goods are not, then $T^{*} = -P^{*}$. The rate of total factor productivity change is measured by the reduction in output prices made possible by the efficiency gains.

(f) If both input and output prices are changing, then $\dot{T} = \dot{R} - \dot{P} = (R/P)^{\dot{}}$. Total factor productivity change is the increase in real factor incomes deflated by the output price (or an index thereof). These interpretations provide general content to the TFP index. Note that the TFP index cannot be described as a technology change index. Public sector infrastructure investments and human capital changes also produce TFP changes.

2.1.2 The Production Function Approach

Under this approach, the measure of productivity is derived from the transformation function relating outputs and inputs. Let output be produced using several inputs, $(X_1,...,X_n)$, and let the technology be described by a production function:

$$Y = F(X_1,...,X_n). \tag{2.5}$$

Assume (2.5) is a linear homogeneous function. The *ceteris paribus* assumption covers the technology set available to farmers, the existing infrastructure such as roads and markets, as well as transactions costs (legal system, etc.). One of the purposes of productivity analysis is to infer from data only on Y and the Xs the probable contributions to output made by shocks to these background factors. Differentiating (2.5) gives us:

$$F_Y dY = \sum_j F_j dX_j = 0, \tag{2.6}$$

where the F_i are first partial derivatives of the production function, F. The first-order conditions for profit maximization are:

$$P_Y = \lambda F_Y \quad \text{and} \quad -R_j = \lambda F_j, \quad (j = 1,...,n),$$

where P_Y and R_i are the prices of output and inputs and λ is a Lagrange multiplier. Substituting $F_Y = P_Y/\lambda$ and $F_i = -R_i/\lambda$ in (2.6) and multiplying the left- and right-hand sides by $\lambda/P_Y Y$ or $\lambda/\Sigma R_i X_i$, we obtain:

$$\frac{dY}{Y} = \sum_j C_j \frac{dX_j}{X_j}, \tag{2.7}$$

where C_i is the cost share for the *j*th input. This expression holds for small changes when the *background* variables are unchanged. It relates growth in output to growth in factors or inputs. When this equation does not hold, the logic of this development tells us that the background variables have changed. This is the basis for defining total productivity change, T^{*}, as:

$$T^{*} = Y^{*} - \sum_j C_j X_j^{*} = Y^{*} - X^{*}. \tag{2.8}$$

This development of TFP growth from production decisions leads to the same expression as when using the accounting identity as our starting point. Constant scale economies were imposed to obtain this relationship. Technical errors by farmers in obtaining maximum output, profit maximization errors, and scale economies may be included in measures of T^{*} in practice.

2.1.3 Index Numbers and Functional Forms

The basic TFP indexes, which are given in equation (2.4), require index numbers for aggregate outputs and inputs, or for output prices and input prices. The Tornqvist-Theil discrete approximation to the Divisia index is a good approximation when small changes in quantities occur.

This approximation to the Divisia index uses chain-linked weights. Cost or revenue weights for all years are constructed, and the weights used in the index are obtained by averaging the weights for the current and preceding year for all years. The output and input quantity indexes are given in equations (2.9) and (2.10):

$$Y = \ln\left(\frac{Y_t}{Y_{t-1}}\right) = \frac{1}{2}(S_{it} + S_{it-1})\ln\left(\frac{Y_{it}}{Y_{it-1}}\right), \tag{2.9}$$

When changes are large, any index number formula will impose an implicit curvature on the production technology. This comes about because the index number for a quantity aggregate is

$$X = \ln\left(\frac{X_t}{X_{t-1}}\right) = \frac{1}{2}(C_{jt} + C_{jt-1})\ln\left(\frac{X_{jt}}{X_{jt-1}}\right). \qquad (2.10)$$

designed to purge the aggregate of price change effects. If prices do not change or if all prices change proportionately, this does not pose a problem. In practice, of course, prices do change from one period to the next. The Fisher index, when chained, is also an appropriate index for these purposes.

In practice, not only is the Tornqvist-Theil index a discrete approximation to a Divisia index, it is also the appropriate index for a linear homogeneous translog technology and for a second-order differential approximation to any arbitrary non-homothetic production technology. This is because the translog function is a flexible functional form, in the sense that it is a good approximation to any arbitrary production (cost or profit) function.

2.1.4 PFP Measurement

Partial Factor Productivity (PFP) measures simply relate output, either a single output or an aggregate index, to a single input and not to a weighted aggregate of all inputs. These indexes are widely used for two reasons. First, they are easy to calculate as no price weighting is required. Second, they have a clear physical interpretation as opposed to the economic interpretation of the TFP indexes.

Labor productivity indexes, which measure output per worker, are widely used in descriptions of general economic activity. Land productivity indexes, i.e. yields or output per unit land, are widely used for agriculture. The indexes, as noted, have a clear physical interpretation, and this is often useful in comparing economic conditions over time or across regions. Changes in PFP indexes stem from two sources. One source is changes in other inputs, for example, fertilizer or labor. The second source is the same set of factors that change TFP indexes.

In interpreting PFP indexes, it is thus important to bear in mind that changes due to other inputs, particularly to increased fertilizer use or irrigation, are not real changes in productivity as noted above for TFP indexes. This consideration also has to be incorporated into statistical decomposition analyses as carried out in Chapters III and IV.

2.2 PFP Indexes for Pakistani Agriculture

It is useful to begin the reporting of productivity measures with the more familiar PFP or yield measures. These have been calculated for wheat, rice, maize, bajra, jowar, cotton, barley, gram, mung, and sugarcane. Table 2.1 reports yield levels for two periods, 1956-66 and 1971-85, for each of three Pakistani states. The first period is the pre-green revolution period. The second is the post-green revolution period. In general, yields were higher for all crops in the 1972-85 period than in the 1956-66 period. Rice yields increased most in percentage terms followed by cotton yields. Wheat and maize yields increased at a modest rate. Yields of gram, barley, sugarcane, bajra, and jowar increased at a slow rate.

Table 2.1: Average Crop Yields: 1956-66 and 1972-85 (Tons per Hectare)

CROPS	PUNJAB		SIND		NWFP		PAKISTAN	
	1956-66	1972-85	1956-66	1972-85	1956-66	1972-85	1956-66	1972-85
Sugar-cane	2.79	3.30	3.43	3.37	2.82	3.25	2.99	3.31
Maize	0.96	1.23	0.52	0.54	1.03	1.33	0.88	1.09
Bajra	0.52	0.58	0.46	0.51	0.38	0.44	0.48	0.55
Jowar	0.49	0.61	0.56	0.62	0.54	0.50	0.52	0.59
Wheat	1.62	1.62	0.70	1.61	0.59	1.03	1.18	1.52
Rice	0.82	1.36	0.83	1.74	0.72	1.42	0.81	1.49
Cotton	0.18	0.23	0.21	0.33	0.72	1.14	0.24	0.38
Barley	0.64	0.72	0.55	0.58	0.62	0.76	0.62	0.69
Gram	0.57	0.59	0.65	0.73	0.43	0.36	0.57	0.59
Mung	0.44	0.59	0.00	0.00	0.32	0.52	0.44	0.58

Table 2.2 reports estimated time trends in yields (PFP) for the eight commodities during the pre-green revolution period, the green revolution period, and the post-green revolution period,

(1972-86). For comparison purposes, Table 2.2 also reports trends in the TFP measure.[19] All trends are estimated by a regression of the form:

$$\ln(X_{it}) = a + bYear + \sum_i c_i D_{it}, \qquad (2.11)$$

where the D_{it} are district dummy variables. In this specification, b is an estimate of the geometric or percentage rate of change per year within the districts in the state. These estimates show that yields generally did increase most rapidly in the green revolution period and that rates of change were highest for rice and wheat. Rates of yield change in the post-green revolution period have generally been low, although most have been positive.

2.3 TFP Indexes for Pakistani Agriculture

Equations (2.9) and (2.10) define the quantity aggregates for the Tornqvist-Theil TFP index. An alternative index number that is also a flexible and superlative index number is the Fisher-Chained index. The Fisher index is the square root of the product of the Laspeyres and the Paasche indexes. Chain-linking it refers to the practice of shifting price weights each period to the previous period and then *linking* changes to produce a cumulated index.[20]

Table 2.3 shows output and variable factor shares for the pre- and post-green revolution periods by province. It is noteworthy that the shares of wheat, sugarcane, and cotton rose during the given time span. On the other hand, the share of rice declined in spite of improved varieties.

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[19] This is discussed in greater detail in section 2.3.

[20] In contrast, equations (2.9) and (2.10) use an average of the previous period and the current period.

Table 2.2: Estimated Time Trend in Yield by Crop (% Change by Year)

CROPS	PUNJAB			SIND			NWFP			PAKISTAN		
	1956-66	1966-72	1972-85	1956-66	1966-72	1972-85	1956-66	1966-72	1972-85	1956-66	1966-72	1972-85
Sugarcane	0.0154	0.0082	0.0012*	0.0158	-0.0052*	0.0185	0.0277	0.0088	-0.0050*	0.0172	0.0043*	0.0049
Maize	0.0140	0.0144	0.0015	0.0297	-0.0371*	-0.0092*	0.0024*	-0.0110*	0.0160	0.0147	0.0027*	0.0017
Bajra	0.0178	0.0072	0.0076	0.0350	-0.0026*	0.0001*	0.0375	-0.0161*	0.0329	0.0248	0.0016*	0.0090
Jowar	0.0170	0.0210	0.0040	0.0158	0.0199	-0.0074*	0.0433	-0.0029*	0.0015*	0.0211	0.0172	0.0003
Wheat	0.0130	0.0390	0.0198	0.0123	0.0906	0.0259*	0.0022*	0.0319	0.0310	0.0109	0.0524	0.0235
Rice	0.0394	0.0646	-0.0119*	0.0068	0.1227	-0.0042*	0.0302	0.0963	0.0198	0.0275	0.0886	-0.0035
Cotton	0.0185	0.0323	0.0108	0.0385	0.0334	-0.0038*	0.0753	0.0127*	-0.0092*	0.0305	0.0304	0.0042
Barley	-0.0067*	0.0228	0.0057	0.0164	0.0044*	-0.0117*	-0.0137*	0.0356	0.0220	-0.0034*	0.0201	0.0048
Gram	0.0047	0.0175	-0.0122*	0.0046*	0.0216	0.0119	0.0668	-0.0263*	0.0094*	0.0155	0.0116	-0.0021*
Mung	0.0317	0.0117	-0.0000*	-	-	-	-	0.0731	0.0249	0.0317	0.0171	0.0033
TFP(FC)	0.0172	0.0253	0.0025	0.0233	0.0725	0.0097	0.0272	-0.0125*	-0.0128*	0.0206	0.0231	0.0019
TFP(TQ)	0.0074	0.0170	-0.0043*	0.0129	0.0628	0.0008*	0.0193	-0.0235*	-0.0184	0.0110	0.0231	0.0086

Note: * means that $1.7 < t < 2.0$, while ** means $2.0 < t$

Table 2.3: Output and Variable Factor Shares

CROPS	PUNJAB		SIND		NWFP		PAKISTAN	
	1956-66	1972-85	1956-66	1972-85	1956-66	1972-85	1956-66	1972-85
OUTPUT SHARES								
Sugar-cane	0.149	0.189	0.080	0.125	0.179	0.196	0.135	0.169
Maize	0.030	0.029	0.001	0.002	0.184	0.154	0.048	0.043
Bajra	0.041	0.027	0.033	0.014	0.031	0.152	0.037	0.021
Jowar	0.020	0.017	0.042	0.015	0.014	0.128	0.025	0.016
Wheat	0.393	0.413	0.165	0.254	0.356	0.355	0.321	0.358
Rice	0.125	0.106	0.403	0.325	0.024	0.034	0.187	0.157
Cotton	0.110	0.132	0.169	0.208	0.009	0.014	0.108	0.134
Barley	0.006	0.004	0.03	0.003	0.020	0.011	0.007	0.005
Gram	0.064	0.043	0.038	0.031	0.067	0.054	0.057	0.042
Mung	0.009	0.009	-	-	-	0.008	0.005	0.006
Tobac-co	0.025	0.009	-	-	0.084	0.116	0.028	0.025
Rape & Must'd	0.028	0.022	0.065	0.020	0.028	0.027	0.039	0.022
VARIABLE FACTOR SHARES								
Labor	0.561	0.519	0.526	0.621	0.559	0.626	0.551	0.567
Animal Labor	0.419	0.268	0.463	0.262	0.429	0.267	0.433	0.266
Trac-tors	0.018	0.150	0.009	0.049	0.010	0.070	0.015	0.108
Ferti-lizer	0.002	0.062	0.001	0.067	0.001	0.035	0.001	0.059

Variable factor shares show that fertilizer use increased rapidly and that tractor power was rapidly replacing animal power in Pakistani agriculture.[21] Figures 2.1, 2.2, and 2.3 depict the Tornqvist-Theil index for the average district in the Punjab, Sind, and NWFP respectively. The base period for each district is the 1956-60 average. This procedure eliminates much of the early period

[21] Appendix B, Table B.1 gives the annual quantity indexes for each output and variable input.

weather variation and affords a better basis for comparison among states. The same figures also depict Fisher-Chained TFP indexes on the same basis.[22]

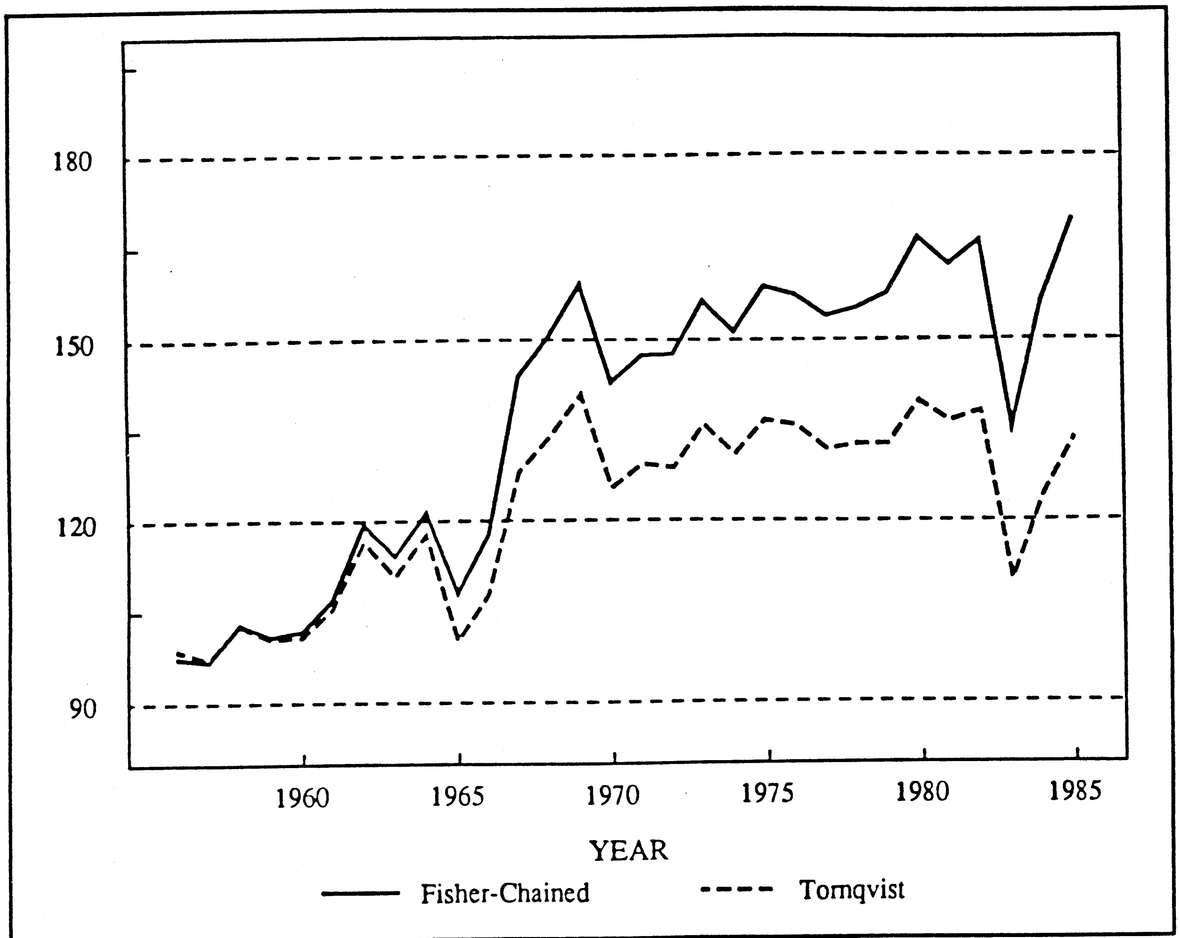

Figure 2.1: TFP Indexes for Punjab Province (Pakistan)

It is readily obvious from these figures that marked differences in TFP growth by region have characterized Pakistan's agricultural sector. In the pre-green revolution period, 1956-66, TFP growth was most rapid in the province of Punjab. The TFP index had risen to 120 by 1962 and remained at that level until 1966. In the province of Sind, the TFP index had risen to only 117 or so by 1966. Interestingly, the NWFP index had also risen to 120 by 1966.

[22] In Appendix B, Table B.2 reports a comparison of Laspeyres, Fisher-Chained, and Tornqvist indexes for Pakistan. Table B.3 reports Fisher-Chained and Tornqvist TFP indexes by province.

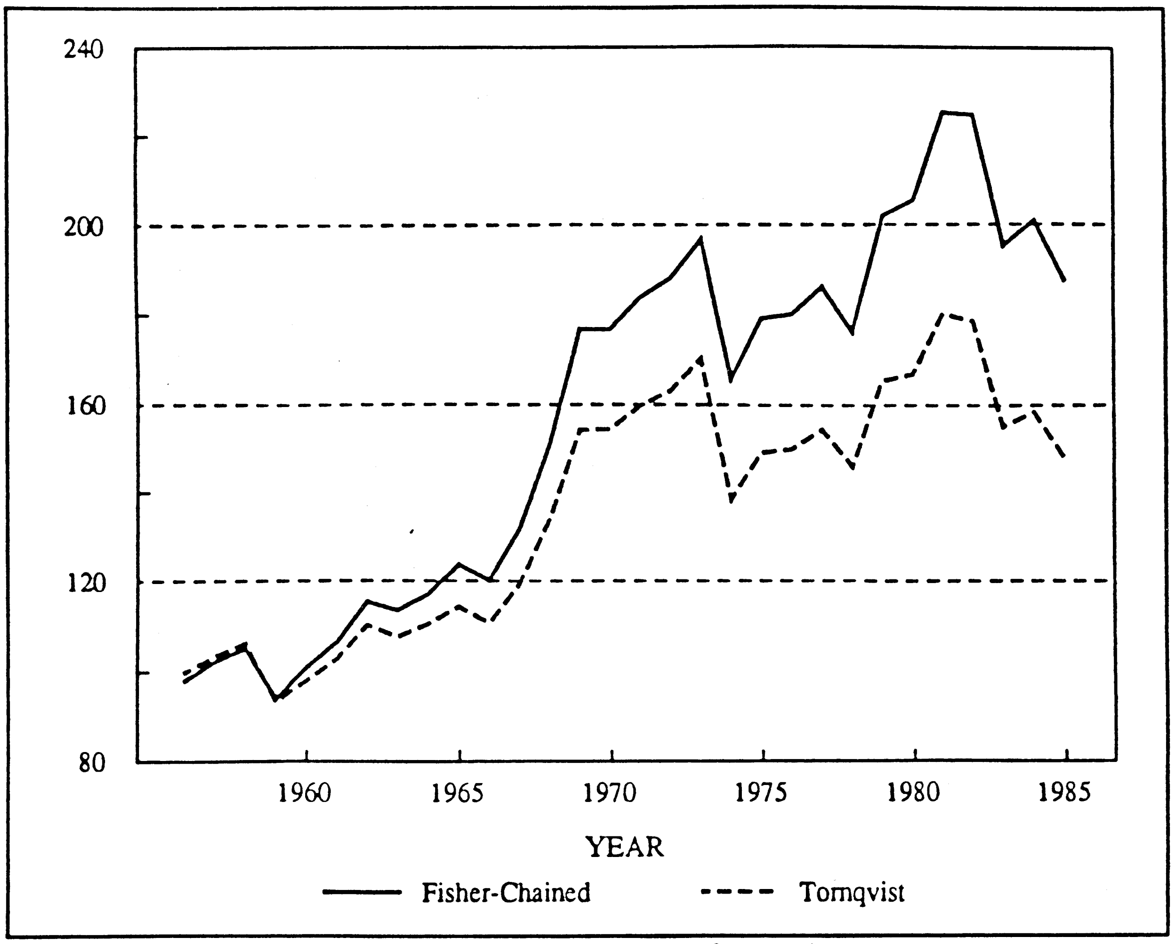

Figure 2.2: TFP Indexes for Sind Province (Pakistan)

During the green revolution period, 1966-1971, TFP rose rapidly in the Punjab, from 115 to almost 150. TFP increased even more rapidly in Sind, from 115 to almost 180. TFP declined in the NWFP. In the post-green revolution years, 1972-85, there was little further TFP growth in the Punjab. The Sind, however, continued to realize relatively rapid TFP growth over this period. TFP growth in the NWFP continued to decline and was well below the 1956-60 level by the early 1980s. The Fisher-Chained indexes follow essentially the same patterns as are apparent in the Tornqvist indexes.[23]

[23] These patterns are not the result of poor weather shocks, since the return of normal weather restores the indexes back to their original path.

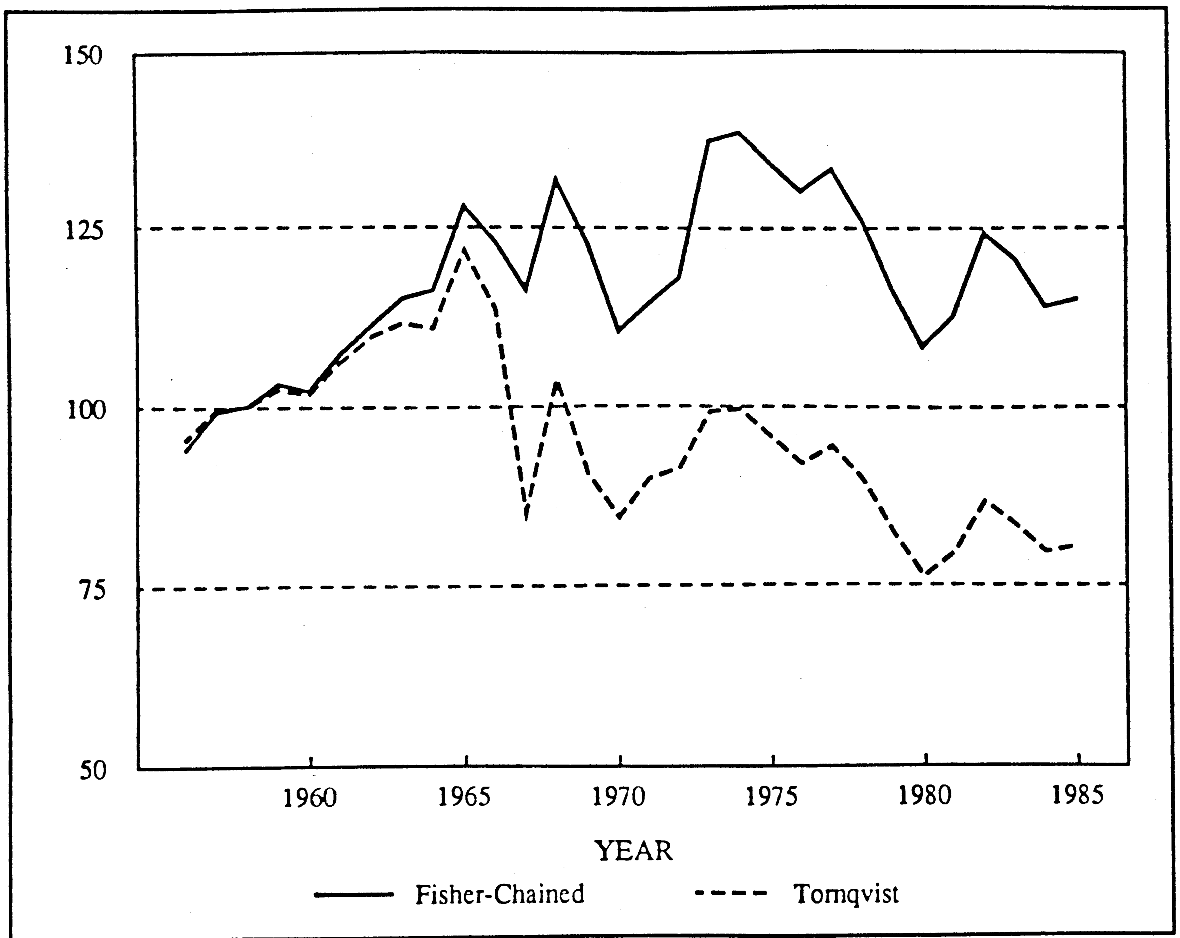

Figure 2.3: TFP Indexes for NWFP (Pakistan)

These results may appear somewhat puzzling to many observers. The Punjab is widely regarded to have the richest resource base of any Pakistani province. The Sind is more dependent on irrigation, while the NWFP is a region of relatively poor and fragile soil resources. However, soil salinity problems have been more severe in the Punjab than in other provinces. It is also felt that the impact of high-yield wheat varieties (HYV) was confined to the early years of the green revolution. Chapter III is dedicated to a more formal analysis of the factors underlying these TFP changes.

2.4 A Comparison of TFP Growth in Pakistan and the Indian Punjab State

Since we have comparable data for districts in the Indian state of Punjab, it is instructive to compare TFP growth under the Indian system with TFP growth in Pakistan. The Indian Punjab is generally regarded to be advantaged relative to the Pakistani Punjab in terms of water quality. Salinity problems have been more severe in Pakistan. Research institutions in the Indian Punjab are also felt to be stronger since, for example, more wheat and rice varieties were developed in India during the post-green revolution period.

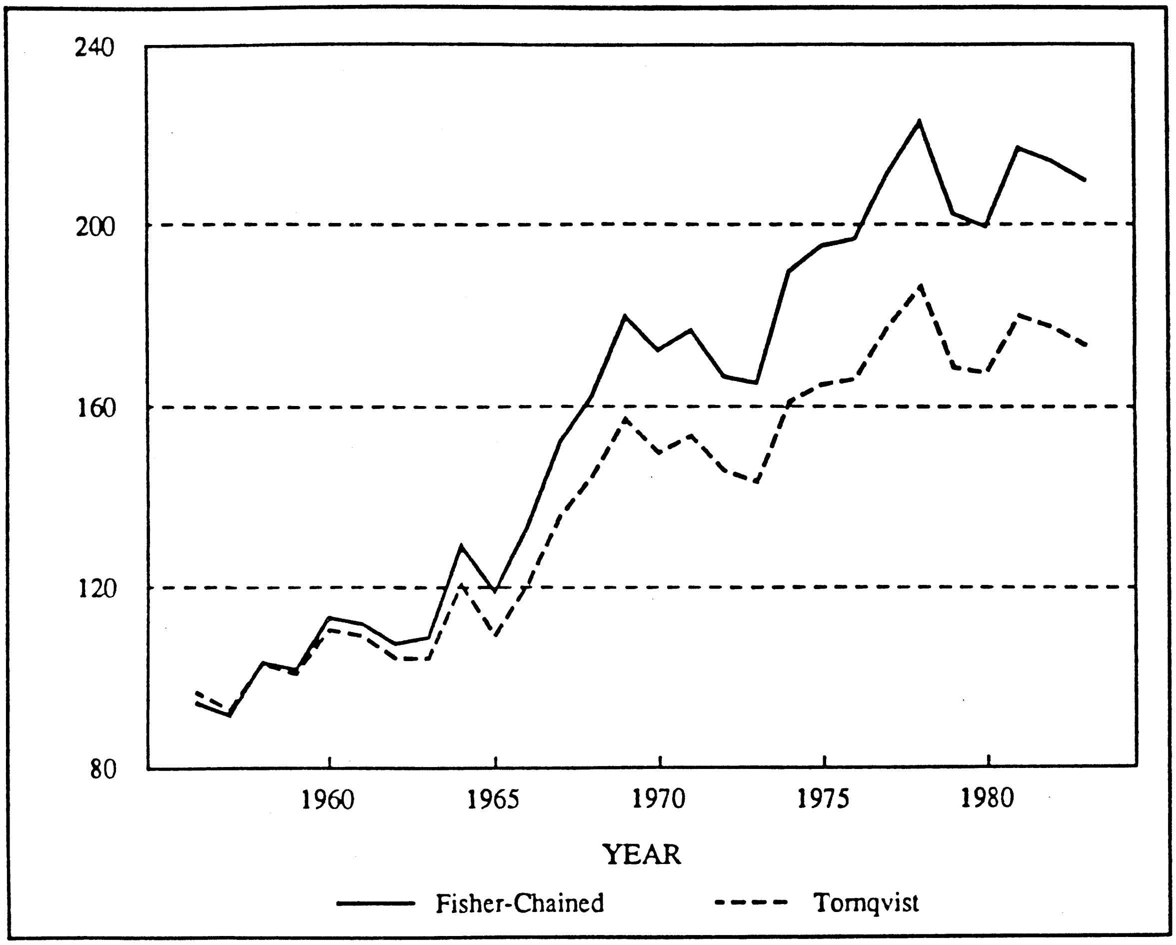

Figure 2.4: TFP Indexes for Punjab State (India)

Figure 2.4 depicts the comparable Tornqvist and Fisher-Chained TFP indexes for the average district in the Indian Punjab.[24] This figure shows that the Pakistani Punjab outperformed the Indian Punjab in the pre-green revolution period (1956-66).

[24] The districts later to be incorporated into the state of Haryana were not included in the indexes.

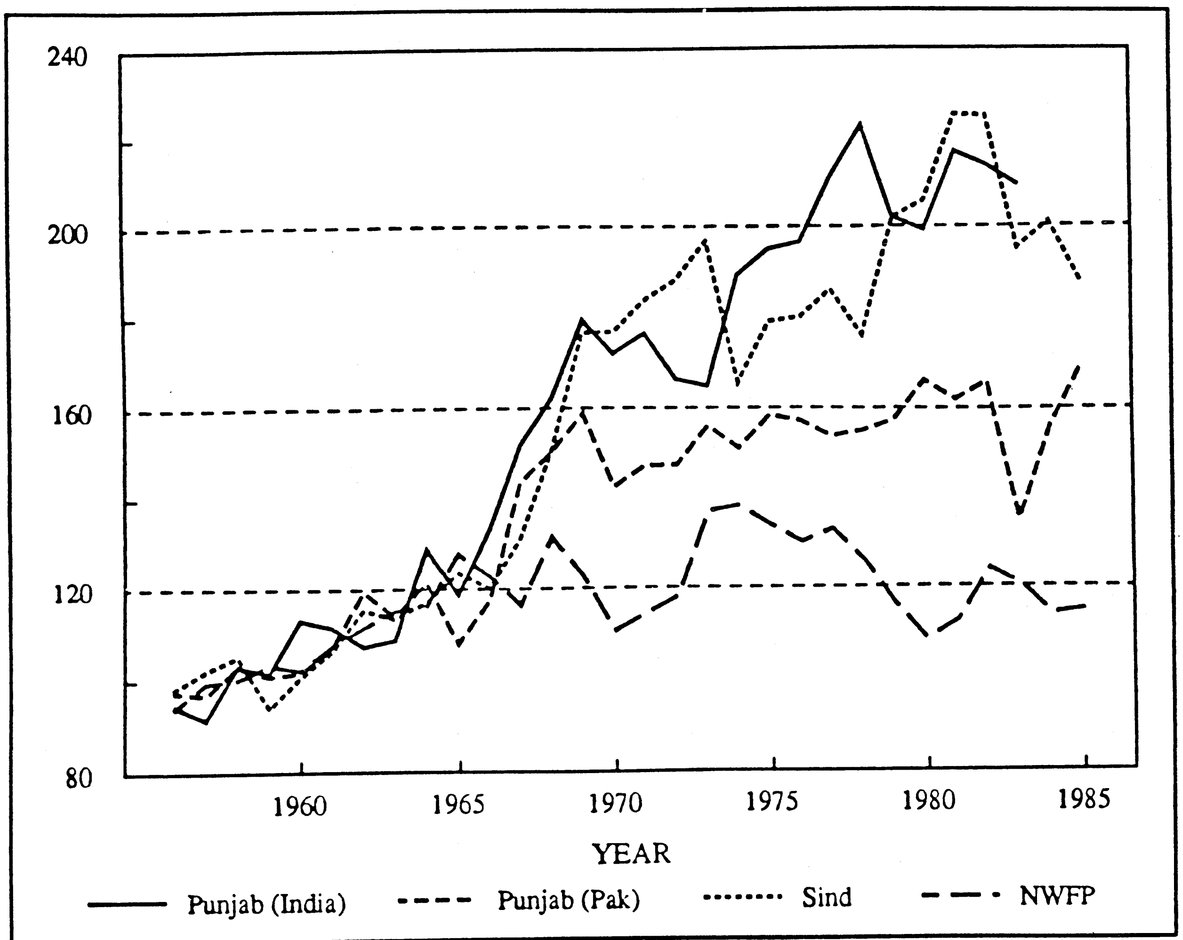

Figure 2.5: Fisher-Chained TFP Indexes (1950-60 = 100)

Both Punjabs performed well during the green-revolution period, but the Indian Punjab clearly outperformed the Pakistani Punjab in the post-green revolution period. In fact, the TFP performance of the Indian Punjab more closely resembles that of the Sind than of the Pakistani Punjab. This is seen most clearly in Figures 2.5 and 2.6, where all four indexes are plotted on a common scale. The NWFP series departed sharply from the other series after 1966. The Pakistani Punjab series departed from the Sind and Indian Punjab series after the early 1970s.

2.5 Conclusion

These TFP calculations are of interest because they raise questions as to the factors underlying their movements. The indicators presented in this chapter were constructed using the most appropriate

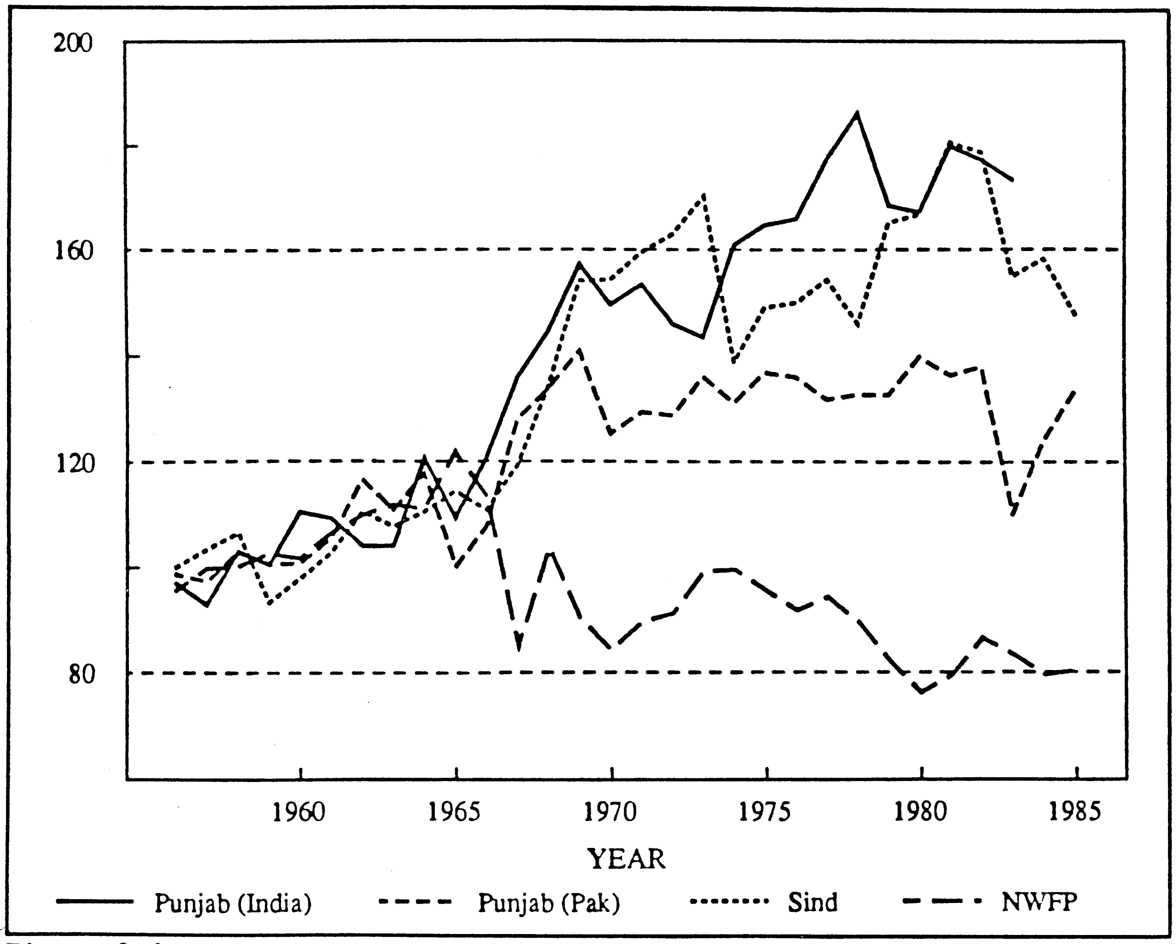

Figure 2.6: Tornqvist TFP Indexes (1950-60 = 100)

methods available, and comparable methods were utilized for each district. This does not rule out the existence of measurement problems in the basic data series, of course, but the resultant series provides food for thought. The following chapters provide a more systematic analysis of factors contributing to these series.

Chapter III

RESEARCH AND TOTAL FACTOR PRODUCTIVITY IN PAKISTANI AGRICULTURE

In this chapter, the question of the determining the factors behind TFP growth in Pakistani agriculture is addressed. The methodology for analyzing TFP growth is quite simple. It entails defining appropriate independent variables for research and infrastructure in a regression, where the dependent variable is the cumulated TFP index for the district. In addition, since there is some possibility of simultaneity bias, the estimating procedure must take this into account.

Section 3.1 discusses the methodological issues in developing TFP decomposition variables. Section 3.2 reports the results of the TFP decomposition analysis. The concluding section summarizes the estimates.

3.1 Methods and Variable Definitions

Recall from Chapter II that TFP measurement procedures attempt to separate output fluctuations into the changes due to variations in input use, and those due to changes in the technology infrastructure and skill levels. TFP decomposition specifications essentially relate TFP growth to changes in technology, infrastructure, and skills by developing variables that measure the *flows* of new technology, infrastructure services, and skill changes. For technology, this requires that variables based on past research and extension programs be developed. For infrastructure, measures of road and communication infrastructure must be developed. In general, there are no strong functional form implications to be derived from optimization theory that can be imposed on this specification unless there is reason to believe that governments actually choose TFP growth-producing projects in an optimizing fashion. It is highly unlikely that the public agencies providing technological and infrastructural services in Pakistan are doing so in a truly optimizing fashion.

In a regression set-up where cumulated TFP indexes are the dependent variable, *appropriate* independent variables should meet two conditions. First they should be exogenous in the context of the system under analysis. If not strictly exogenous, they should at least be predetermined. Techniques exist for correcting for endogeneity bias, and these should be used where required. Second, the form of the variable should be such that there is consistency with the dependent variable over time and across cross-sections.

Consider first the consistency problem. The dependent variable in this case is defined as a cumulated index number with a base of one in the period 1956-60 in each district. This means that it does not depend on the size of the district and that it measures TFP change after the base period. The level of the index at time t is the cumulated change since the base period. The appropriate research variable should, therefore, reflect this cumulation in its timing weights. In addition, it should reflect technological spill-in from outside the district.

The general form for the research variable is:

$$R_{it}^{*} = \sum_{j} G_{ij} \sum_{k} W_{ik} r_{ijt-k}, \tag{3.1}$$

where r_{ijt-k} is research investment in commodity i, region j, in period $t-k$. The research stock is thus based on cumulated past investments and weighted by two sets of weights. The first set, G_{ij}, are spill-in weights measuring the degree to which research conducted in location j is productive in location i relative to the productivity of research conducted in location i. For Pakistan these weights are based on geo-climate regions. The second set of weights are the time-shape weights, W_{ik}. These weights reflect the lag between research expenditure and the ultimate productivity impact. They can also reflect real depreciation of research impacts. These weights are estimated using an iterative procedure described below.

There is also a deflation issue that must be dealt with in cases where research variables must be aggregated across commodities (i.e. over i). For cases where the dependent variable is cumulated TFP, each commodity research variable could be included as a regressor. However, this often results in a high degree of multicollinearity and aggregation is desirable. The aggregation

$$R_t^* = \sum_i S_i R_{it}^* \qquad (3.2)$$

is reasonable if one presumes no spill-over between research programs, that is to say, research on commodity j does not enhance productivity for commodity i.

In the analysis undertaken in this chapter, three variables are designed to characterize the cumulated flow of new technology to a district:

APPRES: This is an aggregate cumulated commodity research stock. The time weights estimated are: 0.0 for $k = 0,...,4$; 0.2 for $k = 5$; 0.4 for $k = 6$; 0.6 for $k = 7$; 0.8 for $k = 8$; and 1.0 for $k > 8$.[25] Research expenditures are associated with geo-climate regions and presumed to spill freely within the region. Commodity shares are used to form the aggregate variable, as given in equation (3.2).

GENRES: This is a cumulated research stock based on expenditures that are not commodity specific. It is constructed in the same manner as APPRES.

SHHYV: The proportion of wheat, rice, and cotton area planted to high-yielding varieties.

The variables are not directly deflated by the number of farms, but the commodity weights are implicitly deflated by the number of commodities. The time weighting is consistent with the cumulated form of the TFP index, as opposed to an annual change form.

The specification also includes several infrastructure or skill level variables:

MKTDISTANCE: This is a measure of investment in markets. It is the average distance for farms in a district from major market centers.

FARMSIZE: This is the average farm size in the district, defined as: Crop Area/Number of Farms.

IRRIGSH: This is the proportion of the cropped area under irrigation.

[25] See also Table 3.2.

CANALSH:	This is the proportion of the cropped area irrigated by canal.
TUBEWSH:	This is the proportion of the cropped area irrigated by tubewells.
RAIN:	This is the level of rainfall in the cropping month.
ROADS:	This is the ratio of Paved Roads:Cropped Area (km/ha).
POPDENSITY:	This is the ratio of Rural Population in 1960:Cropped Area in 1985.

The simultaneity problem is likely to affect the variables FARMSIZE, IRRIGSH, and TUBEWSH most severely. They are likely to respond to TFP growth, although usually with a lag. In the estimation they are treated using simultaneous equation methods.

Table 3.1 summarizes the variables utilized in this analysis. Means for the variables are also reported. All variables are measured at the district level for the years 1956 to 1988.[26] There are two alternative measures of TFP to be analyzed, the Tornqvist-Theil approximation to the Divisia index (TFP-TQ) and the Fisher-Chained index (TFP-FC). The indexes are based on the 1956-60 period in each district and are cumulated over time.

To explore the question of simultaneity, it is possible to test whether markets, farm size, and tubewell irrigation investment may be simultaneously determined with TFP growth.[27] Several of these variables are transformed into natural logarithms as indicated.

3.2 TFP Decomposition Estimates

3.2.1 Estimation of the Timing Weights

The first step in the TFP decomposition is to estimate the timing weights for the research variable. This was done by an appropriate non-linear least squares procedure, which entailed constructing alternate time weights for the variables measuring research; APPRES, GENRES, and the interaction

[26] Appendix C provides further details regarding data collection and measurement.

[27] See Table 3.2 for the full specification.

Table 3.1: Variable Definitions and their Means: TFP Decomposition

VARIABLE	DEFINITION	MEAN
Endogenous		
TFP-TQ*	District cumulated Tornqvist TFP index (1956-60 = 100)	4.757
TFP-FC*	District cumulated Fisher-Chained TFP index (1956-60 = 100)	4.895
MKTDISTANCE	Average distance from a major market center (km)	18.203
FARMSIZE	Cropped area/Number of farms	3.070
TUBEWSH	Proportion of irrigated area under tubewells	0.114
Exogenous		
I. Technology		
SHHYV	Proportion of cropped area planted with high-yield varieties (IRRI wheat, Moxipak wheat, Pakcotton)	0.302
APPRES*	Cumulated stock of applied research investment weighted by commodity shares (see text)	3.805
GENRES	Cumulated stock of general research investment, unweighted (see text)	1430
SHGRAD	Proportion of research personnel holding graduate degrees	0.390
II. Skills		
LITERACY	Percentage of literate rural adult males	20.660
III. Infrastructure		
IRRIGSH	Proportion of cropped area under irrigation	0.686
CANALSH	Proportion of irrigated area irrigated by canals	0.728
TUBEWSH	See above	0.114
ROADS	Km of paved roads/1985 cropped area	1.846
MKTDISTANCE	See above	18.203
FARMSIZE	See above	3.070
POPDENSITY	Rural population in 1960/1985 cropped area	3.305
RAIN	Rainfall in growing season (mm)	394.0
Note: * = variables are transformed to natural logarithms		

APPRES*GENRES.[28] The non-system TFP-TQ specification in Table 3.3, excluding the HYV

[28] See Table 3.3.

variables, was utilized for estimation of the weights. Since the research system itself produces some of the HYVs, it was concluded that the best time weight would be obtained using a specification excluding the HYV variable. This allows the research variables to pick up the combined effect of varietal and non-varietal research contributions.

Table 3.2 reports the mean square errors (MSE) for alternate weighting schemes. As the table shows, the MSE is lowest for weight set 3 for APPRES and weight set 4 for GENRES. These time weights were utilized in the further estimates reported in Table 3.3.

3.2.2 TFP Decomposition Estimates

Table 3.3 reports Two-Stage Least Squares coefficient estimates for a four-equation system and its reduced form TFP-TQ equation. In addition, non-system OLS estimates for both the TFP-TQ and TFP-FC indexes are reported. These TFP measures are calibrated such that the 1956-60 average equals 100. Thus there are no beginning period differences in these indexes. However, to control for fixed effect environmental factors, district dummy variables are included in all TFP equations. This means that any systematic district level factors are taken out of the estimates. In addition, all equations reported include time and time-squared variables to control for any systematic trend factors. Thus the resultant estimates are based on within-district TFP changes and TFP changes that are not correlated with time.

Consider first the system estimates. In this system, MKTDIST, FARMSIZE, and TUBEWSH are treated as endogenous and simultaneously determined with TFP changes. Population density is the key identifying variable. The estimates indicate that there is some simultaneity between TFP, FARMSIZE, and TUBEWSH. TFP growth does appear to have stimulated larger farm sizes and more investment in tubewells. Farm size, in turn, appears to have stimulated TFP growth. Investment in tubewells has not.

Table 3.2: Time Weight Estimates

ALTERNATIVE	t-1	t-2	t-3	t-4	t-5	t
0	0.0	0.2	0.4	0.6	0.8	1
1	0.0	0.0	0.2	0.4	0.6	0
2	0.0	0.0	0.0	0.2	0.4	0.
3	0.0	0.0	0.0	0.0	0.2	0.
4	0.0	0.0	0.0	0.0	0.0	0.
5	0.0	0.0	0.0	0.0	0.0	0.
6	0.0	0.0	0.0	0.0	0.0	0.
7	0.0	0.0	0.0	0.0	0.0	0.
8	0.0	0.0	0.0	0.0	0.0	0.

ALTERNATIVE	t-8	t-9	t-10	t-11	t-12	t-1
0	1.0	1.0	1.0	1.0	1.0	1.0
1	1.0	1.0	1.0	1.0	1.0	1.0
2	1.0	1.0	1.0	1.0	1.0	1.0
3	0.8	1.0	1.0	1.0	1.0	1.0
4	0.6	0.8	1.0	1.0	1.0	1.0
5	0.4	0.6	0.8	1.0	1.0	1.0
6	0.2	0.4	0.6	0.8	1.0	1.0
7	0.0	0.2	0.4	0.6	0.8	1.0
8	0.0	0.0	0.2	0.4	0.6	0.8

ALTERNATIVE		
APPRES	GENRES	MSE
0	1	0.033291
1	1	0.032779
1	2	0.032824
2	2	0.032319
2	3	0.032229
3	3	0.032021
3	4	0.031951
4	4	0.031960
5	5	0.032405
6	6	0.032724
7	7	0.032866
8	8	0.032731

Table 3.3: TFP Decomposition Estimates

Independent Variable	System				Reduced Form	Non-System	
	MKTDISTANCE	FARMSIZE	TUBEWSH	TFP-TQ	TFP-TQ	TFP-TQ	TFP-FC
TFP-TQ	-0.6260	1.5784**	0.0712**	-	-	-	-
MKTDISTANCE	-	-0.0846**	-	0.0079**	-	0.0111*	2.6E-4
FARMSIZE	-	-	-	0.0130**	-	0.0056*	3.4E-4
TUBEWSH	-	-	-	-0.0777	-	-0.1077	0.0587
SHHYV	-	-2.8372**	0.0627	-0.0468	-0.0678	0.0678	-0.0991
APPRES	-	-	-	-0.0222	-0.0211	-0.0139	0.0930**
GENRES	-	-	-	0.0240	0.0292	0.0283	0.1151**
SHHYV*APPRES	-	-	-	0.1633**	0.1758**	0.1455**	0.1269**
SHHYV*IRRIGSH	-	-	-	-0.5725**	-0.6038**	-0.6525**	-0.3984**
SHHYVSQ	-	1.6924*	-0.0279	1.6788**	1.7185**	1.7217**	1.5834**
SHHYVSQ*APPRES	-	-	-	-0.3378**	-0.3433**	-0.3335**	-0.2973**
APPRES*GENRES	-	-	-	-1.8E-6	-3.5E-6	-3.1E-6	8.6E-6*
APPRES*SHGRAD	-	-	-	-0.0193	-0.0213	0.0002	-0.1071
APPRES*SHGRADSH	-	-	-	0.1233	0.1225	0.1089	0.2514**
APPRES*SHIRR	-	-	-	0.1515**	0.1498**	0.1570**	0.0581**
APPRES*LITERACY	-	-	-	-0.0015*	-8.6E-4	-0.0019**	-0.0027**
IRRIGSH	-	-	-	0.0545	0.0410	0.0641	0.2870**
CANALSH	-	-	-	-0.0107	0.0208	-0.0058	0.0587
LITERACY	-	-0.0396**	0.0076**	0.0183**	0.0102*	0.0202**	0.0223**
ROADS	0.8672**	-	-	-0.0658**	-0.0312*	-0.0244	0.0233
POPDENSITY	0.8271**	-	-0.0067*	-	-0.0489**	-0.0574**	-0.1086**
RAIN	-	-	-	-3.2E-5	-1.7E-5	-2.0E-5	-3.6E-5

Note: * = 1.7 < t < 2.0 and ** = t > 2.0

Roads and population density appear to be associated with greater distances to grain markets. The distance to grain markets, however, is not negatively related to TFP growth as expected, which may be due to the fixed effects procedure since results without the fixed effects do share negative impacts. Farm size is positively associated with TFP growth and is higher in the regions with high HYV adoption. The effect of literacy on farm size is negative. Tubewell shares are higher in high literacy districts.

A comparison of the system TFP-TQ coefficients with the non-system estimates shows that there are few large differences. Farm size has a larger input in TFP in the system estimates, but most other estimates are similar, particularly the coefficients on technology inputs.

A comparison of the results for TFP-TQ, the Tornqvist-Divisia indexes, and TFP-FC, the Fisher-Chained indexes, also show little difference due to the specific form of the index measuring TFP. The variables of most interest are the research and HYV variables. Because of interactions, it is difficult to interpret these effects directly. Marginal product calculations show these effects more clearly. The interactions themselves are of some interest.

It first merits noting that applied research does not generally interact positively with more general research. It does interact positively with the level of HYV use when HYV use is low, but not when HYV use is high.[29] Applied research does interact positively with the share of irrigation, showing that it is more valuable in districts with more irrigation. There are weak indications that the higher the proportion of researchers holding graduate degrees, the more productive is applied research. Applied research appears to have a much stronger impact on TFP than does general research.

High yielding varieties are partly imported and partly the product of domestic research. The negative SHHYVSQ*APPRES interaction may be reflecting imported varieties that tend to substitute for domestic research. This variable is probably picking up the early dominance of imported HYVs, especially for wheat. The positive SHHYVSQ term is probably also a reflection of this. Interestingly,

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[29] The SHHYVSQ*APPRES coefficients have negative signs while those on SHHYV*APPRES have positive signs.

the interaction of HYVs with the share of land irrigated is negative, indicating that irrigation has tended to favor domestically produced over imported technology.[30]

3.3 Marginal Products and Marginal Internal Rates of Return

The estimated TFP decomposition equation can be used to compute marginal products for the independent variables. The research variables are of special interest in this context. This requires attention to three problems: the timing and spill-in weights must be used to relate units of product to the research variable; HYV and research variables must be interpreted in a general and consistent manner because research programs themselves produce HYV technology; and general and applied research contributions must be consistently computed.

The methodology for calculating marginal products is based on an evaluation of the partial derivatives of the estimated functions. Since these derivatives are themselves functions of other variables, a particular level of these interaction variables must be chosen to evaluate the effects. The level used in most studies is the mean of the interaction variable, a practice that will be followed here.

The basic concept behind the partial derivative is that this derivative is the calculated change in the dependent variable, in this case the TFP index, due to a one unit change of some independent variable, holding constant the level of all other variables in the expression. Thus for the analysis of research impacts, two further calculations are required to actually compute a rate of return to the investment in research. First, the relationship between investment in some period t and the subsequent change in the research stock variable must be determined. Secondly, the change in TFP must be given an economic value.

Consider the first calculation. An investment, of say 1000 rupees, in a particular region on a particular commodity will ultimately affect the research variable in one or more districts. The timing is governed by the time weights. There is no impact in the first four years after the expenditure is

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[30] I.e., APPRES*IRRIGSH is positive.

made, but the impact is 200 rupees (0.2 x 1000) in the fifth year, 400 rupees by the sixth year, 600 by the seventh year, 800 by the eighth year, and 1000 for the ninth and later years. These weights thus define a future time profile of benefits associated with the investment at time *t*.

The number of districts affected will depend on the spill-in specification. In the case of Pakistan, this is governed by the size of the geo-climate regions. Applied research conducted in a region is specified to spill throughout the region, but not outside the region. Applied research is also specified to produce productivity impacts only on the commodity towards which it is directed. This implicitly deflates the research. This deflator must be used to calculate marginal products. For general research, spill-over occurs across all commodities in all regions. This research is not deflated.

The second calculation requires placing a value on the TFP change. Since the TFP index measures output per unit of input, a change in TFP is equivalent to an increase in output holding inputs constant. This output increase is approximately the increase in consumer plus producer surplus in a market setting. This is illustrated in Figure 3.1.

Suppose that we are at the initial equilibrium point where production is Q_0 and the market clearing price is P_0. A productivity shock that increases per unit output by *k* percent will shift the supply curve to S_1. The change in total surplus is the area *A*, which is k^*Q_0, plus area *B*, the size of which depends on the elasticity of demand. However, since *B* is small relative to *A*, we can approximate total surplus by *k* (the marginal product) times Q_0 (the original output level) times P_0 (the initial price level).

It is actually easier and more straightforward to compute marginal products in two stages. In the first, the marginal product elasticity is found by evaluating ln(*TFP*)/ln(*APPRES*), etc., from the estimated equation. Then in the second step, the marginal product can be evaluated by multiplying the elasticity by the ratio of the value of output to the value of the investment in the research program involved.

Table 3.4 reports estimates of both marginal production elasticities (MPEs) and marginal products (MPs). The marginal products may be interpreted as the added value (i.e., total surplus) of

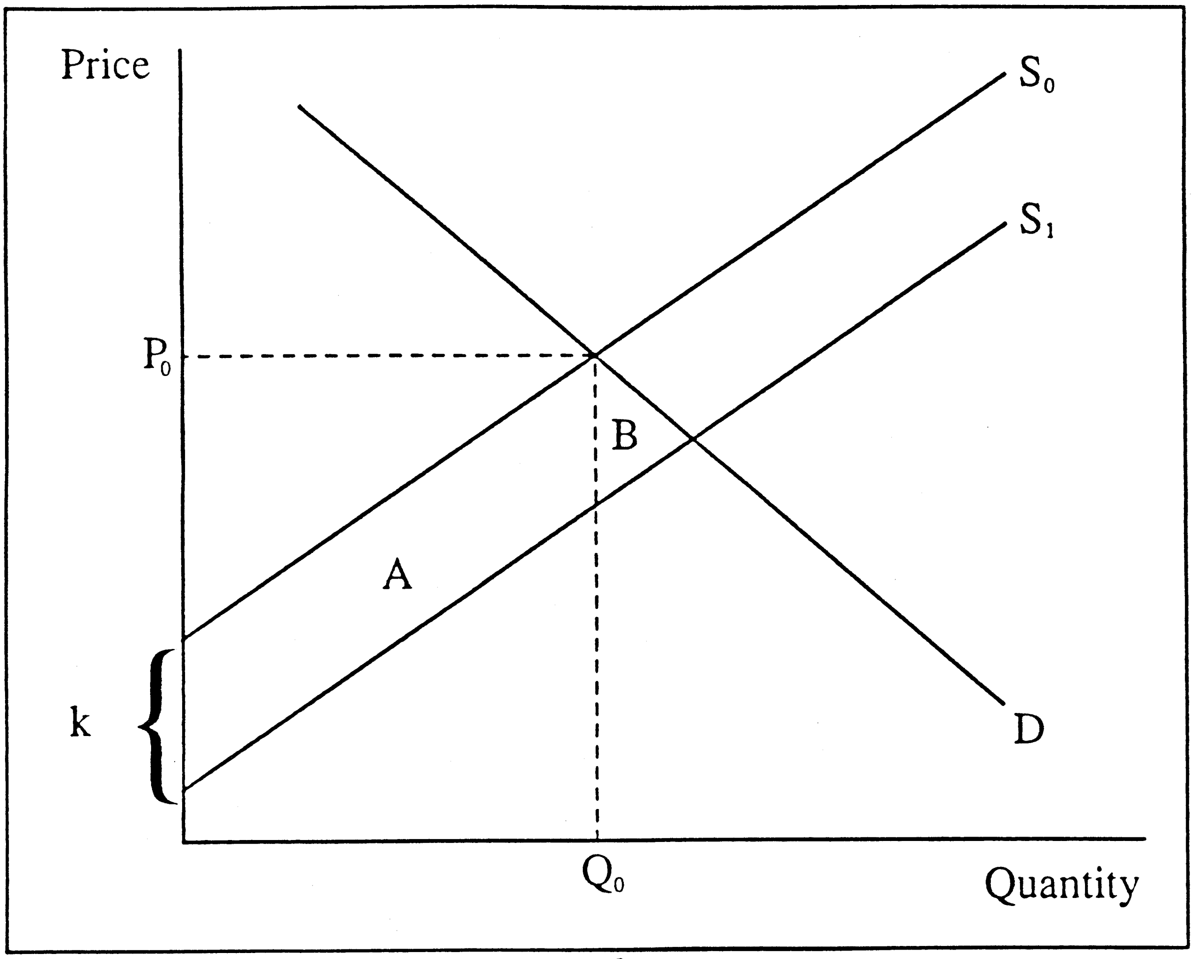

Figure 3.1: Consumer and Producer Surplus

agricultural production or farm output associated with a one rupee investment, after its full impact is realized. The table also reports Marginal Internal Rates of Return (MIRRs) to these investments.

Table 3.4 reports calculations for four specifications for the TFP-TQ index and one for the TFP-FC index. The four TFP-TQ specifications include both the structural and reduced form equations for the system and OLS single equation estimates. The reader can quickly verify that these three specifications yield almost identical results for the MPEs and MPs.[31] Thus it is reasonable to conclude that little simultaneity bias is affecting the results. The fourth equation is the OLS equation used to estimate the timing weights. It excludes HYV variables and is intended to provide an indirect

[31] See Chapter V for MIRR estimates.

Table 3.4: Estimated Research and HYV Marginal Production Elasticities and Marginal Products

Details	Dependent Variable TFP-TQ				TFP-FC
	System Structure	System Reduced Form	OLS Including HYV	OLS Excluding HYV	OLS Including HYV
I. Marginal Production Elasticities					
APPRES	0.05669	0.07313	0.05457	0.16330	0.07663
SHHYV = 0	0.04964	0.06849	0.04272	n/r	0.06535
GENRES	0.01842	0.01876	0.01846	0.05320	0.14157
SHHYV	0.13580	0.14264	0.13214		0.11697
LITERACY	0.18863	0.27740	0.27478	-0.02880	0.27398
IRRGSH	0.26746	0.26486	0.24013	0.19509	0.24688
II. Marginal Products					
APPRES (128)	7.25	9.36	6.99	20.90	9.81
GENRES (192)	3.53	3.60	3.54	10.21	27.18
SHHYV (38)	5.21	5.48	5.07		4.49
All Research	10.96	12.53	10.68	16.61	21.25
III. Marginal Internal Rates of Return					
APPRES	58	64	58	82	65
GENRES	39	40	39	56	75
SHHYV	52	52	51	-	49
All Research	57	60	57	65	70

Notes: Numbers in parentheses are the ratios of agricultural product to investment.
n/r = Not relevant

way of attributing varietal improvements to applied research, APPRES.

The fifth equation is for the TFP-FC index and is intended to show whether the index number construction affects the results. The reader can verify that this specification attributes a larger contribution to general research than other specifications. In Chapter II we argued that the most natural index number specification is the TFP-TQ index, and we prefer to base our interpretation on these specifications. The elasticity estimates are intended to show the percentage change in product or output, holding conventional inputs constant. This is the basis for interpreting them as measures of economic surplus.

There is a strong suggestion that irrigation makes a contribution over and above its normal production contribution. Each elasticity also holds other variables constant. Thus the elasticity for APPRES shows its impact holding constant HYV use, even though most HYV usage is itself the product of applied research. One could consider combining these two contributions.

The marginal product (MP) calculations entail multiplication of the elasticities (MPEs) by the ratio of agricultural product to investment. These ratios, which are reported in parentheses, are calculated as follows:

1. The 1987 ratio of research spending to agricultural product (0.0052, see Chapter I) was the starting point.

2. Eighty percent of total product was assumed to be affected by research and extension.

3. In the absence of an extension variable it was assumed that a one rupee investment in research required a one rupee investment in extension.

4. The total spending on applied research was estimated to be 60% of the total. The remaining 40% went to general research.

5. The equivalent expenditure to achieve a change in HYVs was assumed to be the mean HYV level (0.303). Thus a 10% increase in APPRES leads to a 3% expansion of HYV acreage.

Under these rules, marginal products, (i.e., rupees product per rupee investment after full realization), were computed separately for APPRES, GENRES, and HYV associated research. These estimated marginal products imply high marginal internal rates of return to all forms of investment.[32]

It was also possible to calculate the marginal product for a combined investment in applied and general research by using the 0.6 and 0.4 weights and adding the associated HYV contribution.[33] The estimated MP from the equation excluding HYVs was higher (16.61) than the calculated MP (10.68), suggesting that we may have understated the HYV contribution. However, since some of the HYV contribution is imported, the calculation is probably the more reasonable estimate.

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[32] See Chapter V.

[33] The expression is: MP = 0.6*APPRES + 0.4*GENRES + HYVMPs.

The MIRRs are computed from the marginal product estimates. An investment in period t will generate a stream of economic surplus in the future as indicated by the time weights. The discount rate that makes the present value at time t of the future flow of benefits equal to one rupee is known as the internal rate of return to an investment. It is the interest rate that would allow a bank to pay a depositor the stream of marginal products as the payoff from a one rupee investment at time t. In our case, the payoffs would be zero in the first few years, rising to the full marginal product by year 9 as indicated in Table 3.2. These realized returns to investment are extraordinarily high. They indicate that research investment has been productive. They also indicate a high degree of under-investment in research.

In concluding this chapter, we note that we have found an explanation for a considerable part of the TFP change in Pakistani agriculture. We note that the research system, including varietal, non-varietal, and more general research, contributed to TFP growth. The estimated marginal products of investment in research are high. The estimated returns to investment are high. We will undertake further discussion of these estimates in Chapter V after examining the question further through PFP decomposition analysis in the next chapter.

Chapter IV

Research and Partial Factor Productivity in Pakistani Agriculture

Although Partial Factor Productivity (PFP) indexes are easier to measure and calculate than TFP indexes, their decomposition analysis is more complex. This is because PFP indexes contain the contributions not only of technology, skills, and infrastructure, but of other input changes as well. Accordingly, decomposition specification requires that we deal with this problem of *other inputs*. In addition, since PFP indexes are typically measured for specific crops, there is an additional land quality problem that must also be dealt with.[34] These two problems require a two-stage procedure for PFP or yield decomposition. In the first stage we must predict or estimate land use decisions. In the second stage we take these land use decisions as given and include predicted area variables in the yield decomposition equation. Both stages require that we introduce prices into the analysis, in addition to the technology, skills, and infrastructure variables. Furthermore, we are constrained somewhat in the way we define and use these variables.

Section 4.1 discusses the methodological issues involved. Section 4.2 reports decomposition results. Section 4.3 reports estimated marginal elasticities and marginal products of research variables.

4.1 Methods and Variable Definitions

As noted above, we have two problems in PFP decomposition that we did not have to address in the TFP decomposition analysis. One is the *other inputs* problem, which requires that we develop variables controlling for, or correcting for, the unobservable inputs other than land. The second is that since

[34] This crop specificity is the primary reason PFP indexes are used.

land is not homogenous across districts or farms, there is a *land quality* problem. We may observe, for example, that when the acreage planted in soybeans increases in a district, the land may be of higher or lower quality than land planted with soybeans in the past.

Were it not for this second problem, the most natural way to handle the other inputs problem would be to utilize the duality between transformation and profits functions and use both output and input prices to correct for missing inputs. However, this limits the interpretation of estimated commodity research program impacts. In this chapter, we develop an approach that is intermediate in some sense between the TFP decomposition approach of Chapter III and the duality approach of Chapter V. We utilize prices, but also attempt to take advantage of the fact that farmers do make sequential decisions regarding acreage and other inputs.

4.2 Modelling Acreage Decisions

Consider the farmer's decision regarding the allocation of land to alternative crops. The farmer takes the expected relative prices of other crops, (P_i, P_0), as well as the expected technology available for the crop in question and for other crops, (T_i, T_0), into account. He considers factor prices (P_i) as well. He also takes total farm size as fixed in the short-run.

$$A_i = F(P_i, P_0, T_i, T_0, P_j, S) \tag{4.1}$$

This decision is implicitly a decision to commit other inputs to the process even though there may be a change of plans later. A large literature dealing with supply response models has emerged over the years. Early specifications of (4.1) usually included A_{it-1} as an independent variable to reflect adaptive price expectations and/or cost of adjustment concerns. This older literature has been criticized for failing to consider technology choice (Mundlak 1988) and for imposing expectations that may be unrealistic or even irrational (Eckstein, 1984). The duality literature, on the other hand, does not generally recognize the acreage decision as an independent decision. It focuses instead on the supply decision. Mundlak and McQuirk (1990) have recently argued that the acreage decision is independent because it is made before planting starts and cannot respond to unexpected price changes that may affect yields. They have also argued that technology should be incorporated into the farmers' plans, which can then be looked upon as a two-stage process. First, acreage decisions are made. Then, given the available land, full production decisions determining yield are made. They further note that, for econometric purposes, acreage decisions are not subject to unanticipated weather effects, whereas yield decisions are.

Given acreage decisions, yields are determined by the weather and by factor prices, which also influence the acreage decision. Ideally, we would like to have good product price variables and a reliable weather index for the analysis of yields. Prices, at least prices as measured in Pakistan, tend to vary primarily from year to year, as does weather. There are some differences by region but these differentials tend to be constant over time. We are thus faced with the choice of whether to utilize prices in the yield equation, or to use year and region dummy variables to dummy-out price effects. This decision is also governed by the fact that output-input price ratios themselves reflect productivity changes.[35] After consideration of these factors, we decided to utilize output price ratios and input price ratios (but not output-input price ratios) in the acreage response functions. In the specification, district dummy variables were also used. We then decided to use year and region dummies to dummy-out price effects in the yield equations. This effectively means that we do not estimate full supply elasticities in this analysis.

4.3 Variables and Their Means

Table 4.1 reports variables, variable definitions, and mean values for the PFP analysis. In the first stage, AREA is regressed on the input price ratios, PRFERT, PRLABOR, PRANLAB; the output price ratio, PRICER; the research stocks, APPRES and OTHRES; total cropped area; FARMSIZE; district dummy variables; and year and year squared terms. This is then a fixed effects specification.

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[35] This was discussed in Chapter II.

Table 4.1: PFP Analysis: Variables and their Means

Variable	Definition	Mean
AREA	Area planted to crop (000 hectares)	By crop
PRFERT	Price index for fertilizer/Price index for tractors	0.607
PRLABOR	Price index for labor/Price index for tractors	1.184
PRANLAB	Price index for animal labor/Price index for tractors	0.961
CROPAREA	Total cropped area (000 hectares)	376
APPRES	Research stock for the crop	By crop
SHHYV	Proportion of AREA planted to HYVs	By crop
OTHRES	Research stock for competing crop	By crop
PRICER	Price index for crop/Price index of competing crops	By crop
MKTDISTANCE	See Table 3.1	
FARMSIZE	See Table 3.1	
LITERACY	See Table 3.1	
ROADS	See Table 3.1	
POPDENSITY	See Table 3.1	

MEANS BY CROP

CROP	AREA	APPRES	OTHRES	PRICER
Bajra	20.96	65.8	144.6	0.656
Jowar	12.37	65.8	143.7	0.574
Maize	14.07	65.8	143.9	0.597
Rice	44.84	21.8	163.0	1.119
Wheat	160.89	183.0	109.0	0.475
Cotton	53.89	285.0	121.0	4.858
Sugarcane	18.28	71.0	159.6	1.094

In the second stage, the logarithm of the yield index, which takes the 1956-60 average in each district to equal 100, is regressed on: crop research variables, ln(APPRES) and SHHYV; MKTDISTANCE; FARMSIZE; LITERACY; ROADS; POPDENSITY; and the predicted acreage index for the crop.[36] The specification also included year dummy variables and geo-climate regional dummy variables. These variables are expected to control for price effects on yields. They also reflect weather effects and some trends in productivity. We do not attempt to interpret them, however, as our interest is in the research variables.

4.4 Stage I: Acreage Decision Estimates

Table 4.2 summarizes the acreage response estimates. We expect acreage for each crop to respond positively to its related output price (PRICER) and to its own research flow (APPRES). We expect a negative response to the research attention directed to substitute crops.

Table 4.2: PFP Analysis: Area Coefficient Estimates

CROPS	R^2	PRICER	APPRES	OTHRES	PRFERT
Bajra	0.88	1.904	0.034*	-0.058**	-0.966
Jowar	0.88	-0.170	0.055**	-0.011**	-0.121
Maize	0.96	-1.143**	-0.014**	-0.003	1.762**
Rice	0.95	4.095**	-0.654**	-0.075**	-2.634
Wheat	0.95	13.757**	-0.019	-0.016	0.859
Cotton	0.94	-0.920	-0.048**	0.100**	7.620**
Sugarcane	0.90	-1.906**	-0.037**	0.020**	-0.080
CROPS	**PRLABOR**	**PRANLAB**	**CROPAREA**	**FARMSIZE**	
Bajra	7.231**	-0.350	0.079**	-0.001	
Jowar	0.801	1.144	0.002	0.001	
Maize	0.913	-1.475	0.019**	0.002	
Rice	-5.382**	10.828**	0.057**	-1.611	
Wheat	-0.857	-11.658**	0.647**	-0.011	
Cotton	0.596	-7.881*	0.136**	0.045*	
Sugarcane	1.029	2.318	0.026**	0.001	

Note: * = 1.7 < t < 2.0 and ** = t > 2.0

We find positive price effects only for wheat and rice. Other cereals show little response to prices. We find the expected responses to research flows in all the cereals except wheat. We find

[36] The predicted acreage index is calculated as: ln(Predicted Acreage) - ln(Predicted Acreage in 1970 in the district).

effects on cotton and sugarcane acreage that are contrary to expectations. We do not wish to conclude that we have identified the full effects of the price on the acreage decision for these two crops.

The input price ratios are not expected to have particular effects.High prices of fertilizer, for example, will have negative effects on fertilizer intensive crops and positive effects on crops using little fertilizer. Similarly, higher wages will stimulate production of crops that use little labor and reduce production of labor intensive crops such as rice. It is difficult to claim many obviously reasonable impacts for these price effects. However, we have probably identified reasonable research effects on decisions.

4.5 Stage II: Yield Effect Estimates

Table 4.3 reports the yield index estimates. Predicted areas are included in these regressions. It is of interest to note that predicted area changes contribute to yield changes as expected in the cereal grains and cotton, but not for sugarcane.

Of most interest are the research impacts on yields. Here we observe positive impacts for all cereal grains and cotton, but not for sugarcane. The cotton impacts appear to be closely related to varietal usage. For wheat and rice, the negative interaction between the HYV and the research variable indicates some substitutability between varieties and research. This is consistent with the fact that a considerable amount of HYV importation occurred in both rice and wheat. Thus we have strong evidence of research and HYV impacts for the three major cereals, maize, wheat, and rice. For bajra and jowar there is positive support for a research impact. For cotton there is also support, but it is mixed. There is no evidence for a research impact on sugarcane.

The effects of other variables in the specification are generally mixed, although statistically significant effects are generally of the expected sign. Market distance has a negative impact on yields. Literacy generally has a positive impact. The POPDENSITY coefficient appears to be picking up a positive impact because it is measuring labor impacts. Since we do not wish to develop a strong interpretation for variables other than the research variables, we simply note that there may be several

Table 4.3: PFP Yield Index Decomposition Estimates

Independent Variables	Commodity Regressions: Bajra	Jowar	Maize	Rice	Wheat	Cotton	Sugar-cane
Predicted Area	0.0490**	0.0672**	0.0594**	0.0327**	0.0240	0.0241	0.0004
APPRES	0.0161	0.0113	0.0622**	0.0243*	0.0837**	-0.5247**	-0.0364**
SHHYV				0.4735**	1.4860**	0.0609	
APPRES* SHHYV				-0.3182*	-0.2094**	0.1280**	
MKT-DISTANCE	-0.0019	-0.0049**	-0.0053**	0.0010	0.0042	-0.0033	-0.0052**
FARMSIZE	0.0002	-0.0010**	-0.0001	-0.0001	-0.0003	0.0001	-0.0000
LITERACY	0.0029	0.0049**	0.0004	-0.0002	-0.0018	-0.0075**	0.0059**
ROADS	-0.0216	-0.0491**	-0.0137	-0.0051	-0.0515**	0.0352**	-0.0209**
POP-DENSITY	0.0794**	0.0579**	0.0178*	0.0078	0.1489**	0.0550**	0.0177**
R^2	0.384	0.489	0.734	0.754	0.695	0.628	0.444
F	10.84	18.73	46.04	45.47	43.69	24.59	13.51

Note: * = 1.7 < t < 2.0 and ** = t > 2.0

ways by which population density has a positive impact on crop yields. We believe that this variable is contributing to improved estimates of the research impacts.

4.6 Marginal Products and Marginal Internal Rates of Return

We have two options regarding marginal product calculations. We could consider the yield index marginal products to be the primary impacts of the research variables. However, there is also reason to evaluate the impacts of research programs on acreage decision and then treat the predicted area impacts on yields as being research induced. Both calculations are reported in Table 4.4.

The procedure utilized to compute marginal products is to first compute marginal product elasticities from the estimated yield and acreage equations and then to convert these to marginal products using product-investment ratios.[37] Marginal products are thus the value of annual increased product per rupee invested after the full impact of the investment is realized.

Table 4.4: PFP Analysis: Marginal Production Elasticities and Marginal Product Estimates

CROPS	Estimated Elasticities				Estimated Marginal Products		MIRR	
	APPRES	HYVs	ALL	ALL (A)	ALL	ALL (A)	ALL	ALL (A)
Bajra	0.0494		0.0494	0.0547	3.06	3.39	0.42	0.44
Jowar	0.0672		0.0672	0.0864	4.17	5.36	0.48	0.52
Maize	0.0594		0.0594	0.0627	3.68	3.88	0.45	0.46
Coarse Cereals	0.0571		0.0571	0.0663 (0.0541)	3.54	4.11 (3.35)	0.45	0.47
Rice	0.0159	0.1090	0.0448	0.0546	22.40	27.30	0.84	0.89
Wheat	-0.0050	0.2446	0.1088	0.1087	16.53	16.52	0.76	0.76
All Cereals			0.0851	0.0910 (0.0831)	21.17	22.64 (20.87)	0.83	0.84
Sugar	-0.0364		-0.0364	-0.0365	< 0	< 0	-	-
Cotton	-0.0555	0.5328	0.3483	0.3428	43.53	43.52	1.02	1.02
All Crops			0.1585	0.1605 (0.1580)	26.31	26.64 (26.62)	0.88	0.88

Note: The ALL (A) estimates include the acreage effects. Numbers in parentheses include the indirect effects of other research.

Table 4.4 reports elasticities separately for applied research and HYV impacts. It is probably most reasonable to consider the combined elasticities and marginal products as the full contributions of applied research. We have not considered general research estimates in this analysis, and it is probably reasonable to attribute some of these gains to general research. As noted earlier, sugarcane research appears not to have had a PFP impact. For wheat and cotton, the impact is entirely through the HYV variable. For rice, most of it is through the HYV variable. The HYV elasticities are converted to expenditure elasticities by assuming that all expenditures were required to produce the HYVs.

[37] Estimated yield and acreage equations are given in Tables 4.2 and 4.3. See Table 1.5 for product-investment ratios by commodity.

Marginal products were computed using the product-investment ratios reported in Chapter I, assuming that a one rupee investment in extension and related activities is required per rupee invested in research. The actual calculations turn out to be generally consistent at the aggregate level with those reported in Chapter III. The marginal products for all commodity applied research is higher (26 versus 16), but if the applied research impacts actually include a substantial part of the returns to general research, the estimates reported in Table 4.4 are consistent with those reported in Table 3.4. Marginal internal rates of return are computed from the marginal products using the estimated weight schemes reported in Table 3.2. These rates of return are the rates realized from an investment in period *t* that produces the marginal product indicated over the future time periods. These rates of return are all extraordinarily high except in case of cotton. They are discussed in the context of a general investment program and in the context of estimates reported in other studies in Chapter V.

Chapter V

Summing Up the Contribution of Agricultural Research

This study has documented the institutional development of the agricultural research system in Pakistan and has pursued several methods to evaluate the contribution of this system. In this final chapter, we summarize the conclusions and estimates of each chapter and compare them to conclusions and estimates obtained in other studies.

Chapter I documented the growth and development of the agricultural research system in Pakistan after independence. Pakistan did not inherit extensive research capacity from its colonial period. It thus faced a major institutional challenge in building research programs suited to its agricultural conditions. In Chapter I we provided a quantification of the ways in which Pakistan has addressed this challenge. We noted that, even though Pakistan was without extensive research capacity after independence, it did build a set of research centers and programs that is today roughly comparable to institutions in other countries in the region.

The standard quantitative indicators for research investment show that Pakistan has achieved approximately the same ratio of annual research investments to the value of agricultural product as in other South Asian and low-income developing countries. However, the allocation of research programs between regions and among commodities is probably somewhat more unequal or unbalanced, than in other developing economies. There are also indications that the system has been subject to budgetary stress in recent years, in the sense that operational support to scientists has been too low. In addition, the system has a low level of basic research backing up its applied research programs when compared with other countries.

The responsibility for agricultural programs and support in Pakistan resides heavily in the provinces. The strongest research institutions and the strongest agricultural universities are provincial. This situation creates potential problems of research duplication and coordination. The Pakistan Agricultural Research Council is responsible for addressing these concerns. The Council has been in place for a relatively short period, and it is still too early to determine its full effectiveness.

Chapter II initiated the process of evaluating the impact of the research program. The major contribution of research programs is to make improved technology available to farms through adaptive research and screening of technology produced abroad. If this technology is adopted by farmers and used effectively, it should lead to productivity gains. Did such gains actually occur in Pakistan?

Chapter II showed that Pakistan did achieve significant gains in Total Factor Productivity and in Partial Factor Productivity for most crops. Some part of these gains was obviously achieved as a result of the rapid adoption of improved *green revolution* high-yielding crop varieties, particularly of wheat, as the late 1960s showed the highest rates of TFP and PFP gains. There were, however, significant differences in the timing and rate of TFP and PFP growth in different districts.

Chapter III sought to identify the source of differences in TFP changes in Pakistan's districts. A TFP decomposition specification was developed and applied to district data for the 1956-85 period. In this specification, TFP growth is statistically related to variables designed to reflect the contribution of research programs and improved infrastructure. The timing pattern between research investment and the ultimate impact that research programs have on productivity growth was also estimated.

The TFP decomposition procedure reported in Chapter III did find significant contributions to TFP change from applied commodity-oriented research, from general non-commodity research, and from varietal improvements, part of which represented imported technology. The timing pattern estimates showed that applied research probably has little impact until four years after investment takes place and does not have its full impact on productivity until eight years after investment.

General non-commodity oriented research has a slightly longer time lag. First impacts are realized after five years, full impacts after nine years.

It is possible to evaluate the marginal product of research investment from the estimated decomposition relationship. This is expressed in rupees of surplus realized when the full impact is achieved per rupee invested.[38] By using the timing estimates it is thus possible to calculate the future value of the surplus as the stream of benefits from a one rupee investment at time *t*. The interest rate or discount rate at which this stream has a present value of one rupee at time *t* is the internal rate of return to the investment. Since it is calculated from a marginal product, it is appropriate to consider it a marginal internal rate of return (MIRR).

5.1 Comparable TFP Studies

Table 5.1 summarizes 45 MIRR estimates reported in 25 different studies where aggregate research programs were the object of study. The table includes seven estimates from Chapters III and IV. It also includes the earlier study of Pakistan by Nagy and the historical study of the British Indian Punjab by Pray. Most of these studies are of the type developed in Chapters II and III. Several of them, denoted with an M, were meta production studies. The Chapter III estimates are reported both for estimates holding HYV constant (i.e., not including HYV benefits in the conclusion) and for estimates which count the HYV benefits. The Chapter IV estimates are for the combined commodities analyzed below.

We first observe that all of the Chapter III and IV estimates are extraordinarily high when considered in an investment context. Rates of return above 20% are relatively rare in any economy unless it is growing rapidly. If an economy such as Pakistan could actually realize returns to all public and private investment in the 40-60% range, its overall rate of economic growth must have been extraordinarily high. Investment in agricultural research, even where the time lags are relatively long

[38] By surplus we mean the increased output attributable to the research program.

as they are in Pakistan, is yielding very high returns and thus is providing economic growth at low cost.

Table 5.1: Estimated Marginal Internal Rates of Return to Aggregate Research Investment in Pakistan and Other Countries

STUDY	COUNTRY	COVERAGE	TYPE	TIME PERIOD	MIRR ESTIMATE
Chapter III	Pakistan	AR - HYV constant	D	1956-85	0.57-0.63
		GR - HYV constant	D	1956-85	0.40
		AR - incl HYV	D	1956-85	0.82
		GR - incl HYV	D	1956-85	0.56
		All research	D	1956-85	0.57-0.65
Chapter IV	Pakistan	Commodity research	D	1956-85	0.88
Nagy (1991)	Pakistan	All research	D	1959-79	0.64
Pray (1978)	Punjab	Res & extension	M	1906-56	0.34-0.44
Evenson & McKinsey (1991)	India	All research	D	1958-83	0.65
Kahlon et al (1977)	India	All research	M	1960-71	0.63
Evenson & Jha (1973)	India	All research	D	1953-71	0.40
Evenson (1987)	India	All research	D	1959-71	1.00
Pray & Ahmed (1991)	Bangladesh	All research	M	1948-81	1.00
Ardito-Berletta (1970)	Mexico	Crop research	M	1943-63	0.45-0.93
Evenson (1982b)	Brazil	All research	D	1970-80	0.60
Silva (1984)	Brazil	All research	M	1955-83	0.23-0.53
Evenson (1986)	Brazil	Field crop research	D	1970/75/80	0.55
		Permanent crop res	D	1970/75/80	0.90
Tang (1963)	Japan	Res & schooling	M	1880-1938	0.35
Griliches (1964)	U.S.A.	Res & extension	M	1949-59	0.35-0.40
Latimer (1964)	U.S.A.	Res & extension	M	1949-59	NS
Evenson (1968)	U.S.A.	Res & extension	M	1949-59	0.47
Cline (1975)	U.S.A.	Res & extension	M	1949-58	0.39-0.47
			M	1959-68	0.32-0.39
			M	1964-72	0.28-0.35
Davis (1979)	U.S.A.	Research	M	1949-59	0.66-1.00
			M	1964-79	0.37
Evenson & Welch (1979)	U.S.A.	All research	M	1964	0.55

STUDY	COUNTRY	COVERAGE	TYPE	TIME PERIOD	MIRR ESTIMATE
Fox (1986)	U.S.A.	AR - Livestock	M	1944-83	1.50
		BR - Livestock	M	1944-83	1.16
		AR - Crops	M	1944-83	1.80
		BR - Crops	M	1943-77	0.36
Norton (1981)	U.S.A.	Cash grains	M	1974	0.85
		Livestock	M	1974	0.88
Evenson et al (1979)	U.S.A.	All research	D	1868-1926	0.65
		Appl Research	D	1927-50	0.95
		Basic Research	D	1927-50	1.10
		Appl Research	D	1948-71	0.93-1.30
		Basic Research	D	1948-71	0.45
Huffman & Evenson (1989)	U.S.A.	AR - Crops	D	1950-82	0.45
		AR - Livestock	D	1950-82	0.11
		BR - Crops	D	1950-82	0.57
		BR - Livestock	D	1950-82	0.83
		Private R&D	D	1950-82	0.83

Note: NS = Not significant; D = Decomposition study; M = Meta production study; AR = Applied research; BR = Basic research; GR = General research

It must be noted that these returns are so high that even if the MPs are substantially over-estimated, the MIRRs are still very high. For example, the MP for applied research, including HYVs, was 20.9, and this gave a MIRR of 82%. Suppose that the 20.9 was overestimated by a factor of five and was actually only 4. A marginal product of 4 still leads to a MIRR of 47%.

A quick glance at the other estimates in the table shows that the Pakistani results are not unusual. High rates of return have been observed in a broad range of countries at different times. There is a high degree of consistency underlying this evidence. Many studies have shown that agricultural research has a high payoff and produces low cost growth.

5.2 Comparable PFP Studies

Chapter IV developed a methodology to estimate the determinants of Partial Factor Productivity growth. Table 5.2 summarizes the Chapter IV estimates and compares them with other estimates on a commodity by commodity basis.

The wheat research productivity estimates indicate that wheat research has been productive in many countries and that it has been particularly productive in Pakistan. Many of the measured impacts were due to the varieties released in the mid 1960s, but national programs have contributed by *adding on* to the original HYV material. The same analysis applies to rice research. In general, returns to rice research are even higher than returns to wheat research. Pakistan's rice research program is highly productive, but is simply too small.[39]

Table 5.2: Estimated Marginal Internal Rates of Return to Crop Specific Research Investments in Pakistan and Other Countries

STUDY	COUNTRY	COMMODITY	TYPE	TIME PERIOD	MIRR ESTIMATE
Chapter IV	Pakistan	Wheat	D	1956-85	0.76
Nagy (1991)	Pakistan	Wheat	M	1967-81	0.58
Evenson & McKinsey (1991)	India	Wheat	D	1959-83	0.50
Ardito-Berletta (1970)	Mexico	Wheat	M	1943-63	0.90
Hertford et al (1977)	Colombia	Wheat	M	1927-76	0.11-0.12
Wennergren & Whittaker (1977)	Bolivia	Wheat	M	1966-75	NS
Yrarrazaval et al (1982)	Chile	Wheat	M	1949-77	0.21-0.28
Ambrosi & Da Cruz (1984)	Brazil	Wheat	M	1974-82	0.59
Chapter IV	Pakistan	Rice	D	1956-85	0.84-0.89
Evenson & McKinsey (1991)	India	Rice	D	1959-83	1.55
Flores et al (1978)	Philippines	Rice	D	1966-75	0.75
	Asia	Rice	D	1966-75	0.46-0.71
Evenson & Flores (1978)	Asia	Rice	D	1950-65	0.32-0.39
	Asia	Rice	D	1966-75	0.73-0.78
	IRRI	Rice	D	1966-75	0.74-1.08
Echeverria et al (1988)	Uruguay	Rice	M	1965-85	0.52
Avila (1981)	Brazil	Rice	I	1959-78	0.87-1.19

[39] Note that we have not included the recent extraordinary gains in Basmati rice productivity in these calculations.

STUDY	COUNTRY	COMMODITY	TYPE	TIME PERIOD	MIRR ESTIMATE
Scobie & Posada (1978)	Colombia	Rice	I	1957-64	0.79-0.96
Hayami & Akino (1977)	Japan	Rice	M	1915-53	0.25-0.27
	Japan	Rice	I	1932-61	0.73-0.75
Hertford et al (1977)	Colombia	Rice	I	1951-72	0.60-0.82
Chapter IV	Pakistan	Maize	D	1956-85	0.46
Nagy (1990)	Pakistan	Maize	D	1967-81	0.19
Evenson & McKinsey (1991)	India	Maize	M	1959-83	0.94
Ardito-Berletta (1970)	Mexico	Maize	I	1943-63	0.35
Hines (1972)	Peru	Maize	I	1954-67	0.35-0.40
Yrarrazaval et al (1982)	Chile	Maize	I	1940-77	0.32-0.34
Martinez & Sain (1983)	Panama	Maize	I	1979-82	0.47
Evenson & Da Cruz (1989a)	Brazil	Maize	D	1966-88	0.30
Evenson & Da Cruz (1989b)	PROCISUR	Maize	D	1979-88	1.91
Griliches (1958)	U.S.A.	Maize	I	1940-55	0.35-0.40
Otto & Havlicek (1981)	U.S.A.	Maize	M	1967-79	1.52-2.10
Chapter IV	Pakistan	Bajra	D	1956-85	0.44
Evenson & McKinsey (1991)	India	Bajra	D	1959-83	1.07
Chapter IV	Pakistan	Jowar	D	1956-85	0.52
Evenson & McKinsey (1991)	India	Jowar	D	1959-83	1.07
Griliches (1958)	U.S.A.	Sorghum (Jowar)	I	1940-57	0.20
Chapter IV	Pakistan	All cereals	D	1956-85	0.81-0.84
Evenson & McKinsey (1991)	India	All cereals	D	1959-83	2.18
Evenson (1987)	Latin America	All cereals	M	1960-82	0.44
	Africa	All cereals	M	1960-82	NS
	Asia	All cereals	M	1960-82	0.50
	IARC - Latin Am	All cereals	M	1960-82	> 0.80
	IARC - Africa	All cereals	M	1960-82	> 0.80
	IARC - Asia	All cereals	M	1960-82	> 0.80

STUDY	COUNTRY	COMMODITY	TYPE	TIME PERIOD	MIRR ESTIMATE
Pray (1979)	Bangladesh	Wheat & Rice	I	1961-77	0.30-0.35
Chapter IV	Pakistan	Cotton	D	1956-85	1.02
Ayer & Schuh (1972)	Brazil	Cotton	I	1924-67	0.77-1.10
Hertford et al (1977)	Colombia	Cotton	I	1953-72	NS
Chapter IV	Pakistan	Sugarcane	D	1956-85	NS
Pinazza et al (1984)	Brazil	Sugarcane	D	1972-82	0.35
Evenson (1969)	South Africa	Sugarcane	M	1945-62	0.40

Note: NS = Not significant; D = Decomposition study; M = Meta production study

For maize research, the MIRRs are a little lower than for rice, but again the evidence is clear. Maize research is highly productive in Pakistan and has been highly productive elsewhere. Griliches (1958) reported the first estimates of this type for hybrid corn, and showed that hybrid corn development in the U.S was an extraordinary success story. It is clear after numerous further studies that there are many success stories, covering virtually all commodities, but particularly in cereal grains.

Chapter IV reported estimates for bajra and jowar as well as for all cereals. As with wheat, rice, and maize, research on bajra in Pakistan has been highly productive, although not as productive as research in India. The results for combined cereals add further to the conclusion that national research programs for cereal grains improvement have been highly productive almost everywhere. The IARC programs for cereal research have been even more productive.

Chapter IV also reported results for cotton and sugarcane research. The high returns to cotton research in Pakistan have been replicated in Brazil. The absence of evidence of sugarcane research impacts in Pakistan stands in contrast to the results in Brazil and South Africa. By international standards Pakistan has preformed well in increasing its all its crop yields. However, there is still great potential for future yield increases.

5.3 A Final Summary

This study reports evidence that has strong statistical support to the effect that Pakistan's agricultural research system has been productive. It has produced high rates of return to investment. It has produced economic growth in agriculture at low cost and that growth has been vital to Pakistan with its rapidly growing population. There is little doubt that investment in agricultural research programs have been among the most productive investments in Pakistan over the past 40 years.

It does not follow, however, that the research system has been as productive as it could have been. This study has noted problems with congruence, especially serious in the case of rice. Currently there are serious problems with the level of research support which is insufficient to allow scientists to get their work done. The system appears to be weak in basic research support.

Nor does it follow that the system has solved all or even some of the major problems. Soil salinity has probably worsened. Our data show severe problems in NWFP and these will have to be addressed. However, it is important to note that agricultural research programs cannot solve all these problems. They are designed to develop technology which will enable farmers to increase their productivity and enable the economy to get more output from the resources at hand.

This they have accomplished. It is clear that even given the flaws in the system, and these are probably not too serious, Pakistan has underinvested in agricultural research. It should have invested more. Among the alternative routes by which an economy can increase output, such as expanding the cropped area, increased irrigation, or increased fertilizer use, research has been a bargain. Indeed, for an economy like Pakistan's, the biggest bargains in the business of providing economic growth are probably the agricultural scientists. Not only are they productive, but they are a low cost input. This study has documented the fact that the real cost of supporting a scientist relative to the costs of irrigation equipment, fertilizer, and other infrastructure, is probably one tenth of their level in developed countries.

Pakistan faces challenges in the future. Its population will double in the next few years. It must double food production merely to maintain per capita food consumption. It has already brought most cultivable land under cultivation. If Pakistan is to meet this challenge, it must realize gains in productivity. To do this it must expand and strengthen its agricultural research system as well as its extension and farm education program. The evidence showing that agricultural research contributes to productivity is abundant. Numerous studies reveal the same conclusion. Agricultural research programs will have to play a larger role in the future. Countries such as Pakistan cannot afford to continue to underinvest in their research system and provide inadequate support to its agricultural scientists.

The overall evidence is clear, indeed overwhelming. Research has an exceptionally high pay-off as reflected in the rates of return estimates. The average return to investment in public and private capital and infrastructure in Pakistan cannot possibly have yielded the returns reported here. Indeed, the aggregate growth of the Pakistani economy would indicate that average rates of return to investment in Pakistan are probably less than ten percent in real terms.

Research can also be seen as a means to purchase economic growth in agriculture. The cost of obtaining a unit of growth via research can be compared with the costs of obtaining a unit of growth via irrigation, land clearing, and through input use. No other growth producing activities have demonstrated that they can achieve lower costs per unit of growth than agricultural research, as demonstrated in this study and reinforced by international comparisons.

This study has shown that research is a bargain in Pakistan. It is a bargain, even though the research system is presently severely stressed by support and skill constraints. These constraints should be relaxed which would make research even more of a bargain. Fundamentally, research is a bargain because the real costs of scientific effort in Pakistan are low relative to the costs of irrigation equipment and capital goods.

Pakistan is underinvesting in research. It is not taking advantage of the growth bargain offered by research. It is underinvesting in both qualitative and quantitative terms. If Pakistan is to meet the massive challenge that it faces regarding agricultural production in the future, it will have to invest more in its agricultural research system. It will have to provide better support to its scientists. It will have to upgrade the skill level of its scientists. It will have to expand its research system as well and develop extension and related systems to further support its research program. Only then will it be able to expand agricultural production at a rate sufficient to meet the development challenge that lies ahead.

APPENDIX A

Table A.1: Research Expenditures per Scientist in Selected Asian Countries (1980)

COUNTRY	$US 000's
Malaysia	56.4
Papua New Guinea	45.9
Indonesia	30.2
India	21.8
Bangladesh	16.2
Philippines	15.5
Thailand	15.3
Nepal	12.4
Sri Lanka	10.9
Pakistan	8.9

SOURCE: World Bank Report, 1988

Table A.2: Budgets of Selected Agricultural Research Establishments (Millions of Rupees)

NO.	INSTITUTE	1977-78	1988-89	% CHANGE
1	A.R.I., Sariab, Quetta, Baluchistan	3.61	10.40	188.1
2	A.R.I., Tandojam, Sind	5.60	14.09	151.6
3	A.R.I., Tarnab, Peshawar, NWFP	11.67	21.63	187.4
4	Animal Husbandry Laboratory, Karachi, Sind	0.04	0.10	150.0
5	A.Z.R.I., Quetta, Baluchistan	1.75	6.08	247.4
6	Atomic Energy Agricultural Research Center, Tandojam, Sind	4.29	17.00	296.3
7	Cereal Diseases Research Institute, Islamabad	1.39	2.01	44.6
8	College of Veterinary Sciences, Lahore, Punjab	4.07	1.11	-72.7
9	Commonwealth Institute of Biological Control, Rawalpindi, Punjab	2.24	2.17	-3.1
10	Cotton Research Institute, Multan, Punjab	1.75	6.83	290.3
11	Cotton Research Institute, Sakrand, Sind	6.09	6.09	-
12	Directorate of Land Reclamation, Lahore, Punjab	4.85	22.67	367.4
13	Directorate of Marine Fisheries, Karachi, Sind	3.04	3.04	-
14	Directorate of Soil Conservation, Rawalpindi, Punjab	16.47	16.49	0.1
15	Directorate of Wool/Hair and Mutton Production, Multan, Punjab	1.29	6.92	436.4
16	Drainage and Reclamation Institute of Pakistan, Hyderabad, Sind	6.50	4.94	-24.0
17	NWFP Agriculture University, Peshawar, NWFP	3.32	108.59	3170.8
18	Fine Wool Sheep Farm, Sarai Krishna, Mianwali, Punjab	0.42	1.80	328.6
19	Fisheries Research Institute, Qadirabad, Gujranwala, Punjab	0.42	1.23	192.8
20	Institute of Cotton Research and Technology, Karachi, Sind	1.90	4.30	126.3
21	Kamori Goat Farm, Khudabad Dadu, Sind	0.23	0.39	69.5

NO.	INSTITUTE	1977-78	1988-89	% CHANGE
22	Livestock Development Research Farm for Kundi Buffaloes, Rohri, Sind	0.35	1.29	268.6
23	Livestock Experiment Station, Jaba, Mansehra, NWFP	0.08	1.21	1412.5
24	Livestock Experiment Station, Karachi, Sind	0.34	1.34	294.1
25	Livestock Experiment Station, Khushab, Punjab	1.38	2.18	57.9
26	Livestock Experiment Station, Nabisar Road, Tharparkar, Sind	0.43	2.06	379.1
27	Livestock Experiment Station Qadirabad, Sahiwal, Punjab	0.86	2.79	224.4
28	Livestock Production Research Institute, Bahadurnagar, Okara, Punjab	7.03	8.69	23.6
29	Cereal Crops Research Institute, Pirsabak Nowshera, NWFP	2.34	6.78	189.7
30	Maize and Millet Research Institute, Yousufwala, Punjab	1.94	6.51	235.5
31	National Agriculture Research Center, Islamabad	1.45	48.28	3229.6
32	Nuclear Institute of Agriculture and Biology, Faisalabad, Punjab	4.99	21.00	320.8
33	Nuclear Institute of Food and Agriculture, Tarnab, Peshawar, NWFP	2.20	7.50	240.9
39	Oilseed Research Institute, Faisalabad, Punjab	1.41	4.67	231.2
35	Pakistan Agricultural Research Council, Islamabad	62.46	464.46	643.6
36	Pakistan Forest Institute, Peshawar, NWFP	4.90	28.20	475.5
37	Plant Protection Institute, Faisalabad, Punjab	1.60	4.10	156.2
38	Ayub Agricultural Research Institute, Faisalabad, Punjab	29.35	122.09	315.9
39	Rapid Soil Fertility Survey and Soil Testing Institute, Lahore, Punjab	4.80	7.93	65.2
40	Rice Research Institute, Kala Shah Kaku, Punjab	1.75	3.74	113.7

NO.	INSTITUTE	1977-78	1988-89	% CHANGE
41	Sericulture Research Laboratory, Lahore, Punjab	0.50	0.56	112.0
42	Silvicultural Research Division, Hyderabad, Sind	0.18	1.00	455.5
43	Sind Agriculture University, Tandojam, Sind	11.50	109.54	852.5
44	Soil Survey of Pakistan, Lahore, Punjab	4.88	9.83	101.4
45	University of Agriculture, Faisalabad, Punjab	28.20	119.53	322.5
46	Vegetable Research Institute, Faisalabad, Punjab	3.75	1.59	-57.6
47	Veterinary Research Institute, Lahore, Punjab	5.22	17.18	229.1
48	Veterinary Research Institute, Peshawar, NWFP	1.85	8.42	355.1
49	Wheat Research Institute, Faisalabad, Punjab	1.20	3.15	162.5
Total		267.88	1273.13	375.3

Source: PARC Survey, 1988

Table A.3: Staff Qualifications at Selected Agricultural Research Establishments

	1977-78				1988-89			
NO.	B.Sc.	M.Sc.	Ph.D.	Total	B.Sc.	M.Sc.	Ph.D.	Total
1	34	29	3	66	18	25	1	44
2	44	86	1	131	15	88	1	104
3	178	75	5	258	99	104	4	207
4	2	-	-	2	-	2	-	2
5	3	8	-	11	5	35	1	41
6	3	25	15	43	17	40	13	70
7	6	13	3	22	1	16	3	20
8	11	30	2	43	6	46	8	60
9	2	19	4	25	1	7	1	9
10	15	19	4	38	5	33	2	40
11	6	17	1	24	3	28	3	34
12	82	15	-	97	57	20	-	77
13	11	9	-	20	20	15	-	35
14	32	9	-	41	34	23	-	57
15	22	1	-	23	13	1	-	14
16	5	8	-	13	20	11	1	32
17	46	13	-	66	-	111	14	125
18	2	1	-	3	2	1	-	3
19	9	4	1	14	10	14	1	25
20	24	10	1	35	17	11	-	28
21	2	-	-	2	1	-	-	1
22	1	-	-	1	1	1	-	2
23	2	-	-	2	2	-	-	2
24	3	-	-	3	2	-	-	2
25	2	-	-	2	2	1	-	3
26	5	-	-	5	5	-	-	5
27	5	-	-	5	6	-	-	6
28	26	12	3	41	24	21	-	45
29	19	7	2	28	21	25	2	48
30	12	11	2	25	2	32	1	35
31	1	2	1	4	90	207	46	343
32	17	55	20	92	26	53	21	100
33	8	14	3	25	10	30	5	45
39	6	23	2	31	2	37	2	41
35	52	75	17	144	103	471	82	656

	1977-78				1988-89			
NO.	B.Sc.	M.Sc.	Ph.D.	Total	B.Sc.	M.Sc.	Ph.D.	Total
36	25	34	5	64	11	48	10	69
37	1	42	1	44	2	25	1	28
38	187	299	18	504	294	501	25	820
39	19	30	1	50	16	66	1	83
40	11	21	4	36	3	20	2	25
41	3	2	-	5	1	2	-	3
42	4	1	-	5	1	2	-	3
43	23	123	16	162	-	121	46	167
44	26	42	3	71	17	42	-	59
45	47	219	95	361	-	267	120	387
46	1	33	-	34	2	32	1	35
47	45	16	1	62	59	32	-	91
48	16	7	1	24	24	14	1	39
49	3	31	2	36	1	34	3	38
Total	1109	1490	237	2836	1071	2715	422	4208
% Change					-3.4	82.2	78.0	48.4

Source: PARC Survey, 1988

Table A.4: Development and Non-Development Budgets of 50 Agricultural Research and Education Establishments (Millions of Rupees)

YEAR	DEV BUDGET	NON-DEV BUDGET	TOTAL
1978-79	46.0	104.2	150.2
1979-80	48.5	109.1	157.6
1980-81	60.5	124.5	185.0
1981-82	57.8	150.6	208.4
1982-83	69.6	172.8	242.4
1983-84	302.9	243.2	546.1
1984-85	396.4	277.6	674.0
1985-86	331.0	351.8	682.8
1986-87	379.2	404.1	783.3
1987-88	424.1	418.0	842.1

Source: PARC Survey 1988

Table A.5: Non-Development Budgets of 50 Agricultural Research and Education Establishments (Millions of Rupees)

YEARS	SALARIES			OPERATIONAL EXPENSES			TOTAL
	BASIC SALARIES	ALLOW/ MISC EXP	TOTAL	EQUIP-MENT	BUILD-INGS	TOTAL	
1978-79	61.2	16.5	77.7	25.3	1.10	26.4	104.1
1979-80	65.8	16.1	82.4	26.2	0.95	27.1	109.5
1980-81	74.8	17.9	92.7	31.1	0.65	31.8	124.5
1981-82	88.1	27.8	115.9	34.2	0.53	34.7	150.6
1982-83	100.9	29.8	130.7	40.2	1.86	42.1	172.8
1983-84	129.2	67.5	196.7	43.1	3.79	46.9	243.6
1984-85	149.3	78.2	227.5	47.6	2.44	50.0	277.5
1985-86	166.8	112.9	279.7	67.9	4.17	72.1	351.8
1986-87	196.8	115.9	312.7	88.5	2.74	91.2	404.9
1987-88	229.7	120.1	349.8	65.5	2.67	68.2	418.0

Table A.6: Sanctioned and Actual Staff Positions of 50 Agricultural Research and Education Establishments (Number)

YEARS	SANCTIONED STAFF			STAFF IN POSITION		
	TECHNICAL STAFF	SUPPORT STAFF	TOTAL	TECHNICAL STAFF	SUPPORT STAFF	TOTAL
1978-79	3396	5461	8857	2718	5010	7728
1979-80	3504	5687	9191	2707	5058	7765
1980-81	3502	5862	9364	2964	5217	8181
1981-82	3600	5932	9532	3101	5347	8448
1982-83	3713	6024	9737	3462	5448	8910
1983-84	3753	6182	9935	3554	5677	9231
1984-85	3957	6117	10074	3716	5844	9560
1985-86	4046	6131	10177	3929	5916	9845
1986-87	4877	6321	11198	4023	6188	10211
1987-88	5155	6513	11668	4162	6436	10598

Table A.7: Technical Manpower at 50 Agricultural Research and Education Establishments by Degree Earned (Number)

YEAR	Ph.D.	M. Phil.	M.Sc.	H. B.Sc.	B.Sc.	DVM	BVM	OTHER	TOTAL
1978-79	99	11	952	494	246	199	118	678	2718
1979-80	93	10	1090	406	231	126	116	797	2707
1980-81	89	12	1058	578	234	241	107	538	2964
1981-82	111	21	1181	503	235	293	115	499	3101
1982-83	115	15	1325	719	234	274	150	251	3462
1983-84	127	14	1303	785	247	282	153	199	3554
1984-85	137	15	1352	916	256	297	199	241	3716
1985-86	156	17	1471	987	268	269	208	117	3929
1986-87	148	26	1666	907	272	240	198	54	4023
1987-88	199	28	2014	1144	299	217	194	67	4162

Source: PARC Survey, 1988

Table A.8: Analysis of the Current Expenditures of NARC (1985-86 to 1988-89, Millions of Rupees)

CATEGORY	ACTUAL 1985-86		ACTUAL 1986-87		REVISED 1987-88		BUDGETED 1988-89	
	Amount	%	Amount	%	Amount	%	Amount	%
Staff Costs	13.633	48.7	16.525	53.0	21.580	60.8	26.789	70.6
% of 1985-86 Level	(100.0)		(121.2)		(158.3)		(196.5)	
Operational Expenses	10.803	38.6	12.149	38.9	11.426	32.2	9.491	25.0
% of 1985-86 Level	(100.0)		(112.5)		(105.7)		(87.8)	
Capital Expenditures	3.535	12.7	2.520	8.1	2.465	7.0	1.656	4.4
% of 1985-86 Level	(100.0)		(71.3)		(69.7)		(46.8)	
TOTAL	27.971	100.0	31.194	100.0	35.472	100.0	37.936	100.0
% of 1985-86 Level	(100.0)		(111.5)		(126.8)		(135.6)	
Total # of Staff	629		801		787		857	
Total # of Scientists	129		203		200		224	
Operational Exp. per Scientist	0.084		0.060		0.057		0.042	
% of 1985-86 Level	(100.0)		(70.9)		(68.0)		(50.2)	

Table A.9: Analysis of the Current Expenditures of the NARC Wheat Research Program (1985-86 to 1988-89, Millions of Rupees)

CATEGORY	ACTUAL 1985-86 Amount	%	ACTUAL 1986-87 Amount	%	REVISED 1987-88 Amount	%	BUDGETED 1988-89 Amount	%
Staff Costs	0.603	55.6	0.556	59.9	0.743	72.5	1.192	82.8
% of 1985-86 Level	(100.0)		(92.2)		(123.2)		(197.7)	
Operational Expenses	0.420	38.8	0.369	39.7	0.277	27.0	0.239	16.6
% of 1985-86 Level	(100.0)		(87.8)		(65.9)		(56.9)	
Capital Expenditures	0.062	5.7	0.003	0.3	0.005	0.5	0.008	0.6
% of 1985-86 Level	(100.0)		(4.8)		(8.1)		(12.9)	
TOTAL	1.085	100.0	0.928	100.0	1.025	100.0	1.439	100.0
% of 1985-86 Level	(100.0)		(85.5)		(94.5)		(132.6)	
Total # of Staff	60		80		70		70	
Total # of Scientists	22		31		25		32	
Operational Exp. per Scientist	0.019		0.012		0.011		0.007	
% of 1985-86 Level	(100.0)		(63.2)		(57.9)		(36.8)	

Table A.10: Analysis of the Current Expenditures of the NARC Rice Research Program (1985-86 to 1988-89, Millions of Rupees)

CATEGORY	ACTUAL 1985-86		ACTUAL 1986-87		REVISED 1987-88		BUDGETED 1988-89	
	Amount	%	Amount	%	Amount	%	Amount	%
Staff Costs	0.671	49.7	0.744	55.6	1.098	73.9	1.166	80.1
% of 1985-86 Level	(100.0)		(110.9)		(163.6)		(173.8)	
Operational Expenses	0.642	47.6	0.572	42.8	0.381	25.6	0.277	19.0
% of 1985-86 Level	(100.0)		(89.1)		(59.3)		(43.2)	
Capital Expenditures	0.037	2.7	0.021	1.6	0.006	0.4	0.013	0.9
% of 1985-86 Level	(100.0)		(56.7)		(16.2)		(35.1)	
TOTAL	1.350	100.0	1.337	100.0	1.485	100.0	1.456	100.0
% of 1985-86 Level	(100.0)		(99.0)		(110.0)		(107.8)	
Total # of Staff	55		58		59		58	
Total # of Scientists	17		19		21		23	
Operational Exp. per Scientist	0.038		0.030		0.018		0.012	
% of 1985-86 Level	(100.0)		(78.9)		(47.4)		(31.6)	

Table A.11: Analysis of the Current Expenditures of the NARC Maize Research Program (1985-86 to 1988-89, Millions of Rupees)

CATEGORY	ACTUAL 1985-86		ACTUAL 1986-87		REVISED 1987-88		BUDGETED 1988-89	
	Amount	%	Amount	%	Amount	%	Amount	%
Staff Costs	0.584	68.1	0.567	71.0	0.497	66.8	0.757	79.2
% of 1985-86 Level	(100.0)		(97.1)		(85.1)		(129.6)	
Operational Expenses	0.251	29.3	0.232	29.0	0.236	31.7	0.194	20.3
% of 1985-86 Level	(100.0)		(92.4)		(94.0)		(77.3)	
Capital Expenditures	0.022	2.6	0.000	0.0	0.011	1.5	0.005	0.5
% of 1985-86 Level	(100.0)		(0.0)		(50.0)		(22.7)	
TOTAL	0.857	100.0	0.799	100.0	0.744	100.0	0.956	100.0
% of 1985-86 Level	(100.0)		(93.2)		(86.8)		(111.5)	
Total # of Staff	54		52		51		59	
Total # of Scientists	15		18		17		21	
Operational Exp. per Scientist	0.017		0.013		0.014		0.009	
% of 1985-86 Level	(100.0)		(76.5)		(82.4)		(52.9)	

Table A.12: Analysis of the Current Expenditures of the NARC Pulses Research Program (1985-86 to 1988-89, Millions of Rupees)

CATEGORY	ACTUAL 1985-86 Amount	%	ACTUAL 1986-87 Amount	%	REVISED 1987-88 Amount	%	BUDGETED 1988-89 Amount	%
Staff Costs	0.613	61.3	0.677	71.3	0.854	80.5	0.971	87.9
% of 1985-86 Level	(100.0)		(110.4)		(139.3)		(158.4)	
Operational Expenses	0.349	34.9	0.258	27.2	0.206	19.4	0.129	11.7
% of 1985-86 Level	(100.0)		(73.9)		(59.0)		(36.9)	
Capital Expenditures	0.038	3.8	0.014	1.5	0.001	0.1	0.005	0.4
% of 1985-86 Level	(100.0)		(36.8)		(2.6)		(13.1)	
TOTAL	1.000	100.0	0.949	100.0	1.061	100.0	1.105	100.0
% of 1985-86 Level	(100.0)		(94.9)		(106.1)		(110.5)	
Total # of Staff	38		40		40		41	
Total # of Scientists	18		21		21		21	
Operational Exp. per Scientist	0.019		0.012		0.010		0.006	
% of 1985-86 Level	(100.0)		(63.2)		(52.6)		(31.6)	

APPENDIX B

Table B.1: Output and Input Quantities by Year

YEAR	OUTPUT (Thousand of Tons)					
	WHEAT	RICE	COTTON	SUGAR	BAJRA	MAIZE
1955	94.08	23.76	8.23	23.61	9.72	12.01
1956	100.73	23.90	8.37	24.76	10.52	12.80
1957	100.94	24.58	8.36	31.28	8.45	12.85
1958	111.31	28.25	8.09	33.59	9.96	13.41
1959	105.24	25.74	7.81	32.64	9.57	13.16
1960	107.52	29.16	8.26	34.04	8.39	12.51
1961	111.40	32.02	8.88	40.69	10.22	13.14
1962	118.12	33.80	9.99	49.80	11.78	14.28
1963	117.22	35.16	11.35	47.52	10.31	14.03
1964	128.71	39.16	10.37	49.90	13.49	14.84
1965	109.18	36.26	11.35	62.66	10.90	14.55
1966	121.32	37.36	12.75	61.95	10.61	15.64
1967	176.18	41.87	14.13	53.08	11.89	18.96
1968	185.95	56.98	14.47	62.43	10.36	19.77
1969	203.76	66.45	14.70	74.45	8.96	18.87
1970	182.58	60.65	14.88	66.39	10.11	17.88
1971	189.68	62.13	19.39	55.76	10.18	17.99
1972	205.01	64.01	19.22	56.88	8.70	17.23
1973	211.50	67.70	18.06	67.26	9.89	18.44
1974	212.20	63.47	17.40	59.68	7.39	18.91
1975	237.51	71.86	14.13	72.23	8.97	20.28
1976	251.94	75.65	11.95	83.58	8.88	19.88
1977	231.07	81.35	15.79	85.16	9.07	19.39
1978	272.07	89.40	13.00	77.58	9.10	19.84
1979	295.01	86.94	19.96	78.34	8.01	20.31
1980	311.58	83.81	20.45	91.18	6.24	21.89
1981	324.02	87.34	21.43	102.16	7.70	21.36
1982	335.01	85.54	23.61	91.90	6.32	22.64
1983	294.54	83.31	14.20	96.83	7.31	22.99
1984	314.61	83.10	28.88	91.74	8.08	23.46
1985	377.82	73.66	34.83	79.03	7.39	22.05

Table B.1: Output and Input Quantities by Year (continued)

YEAR	OUTPUT (Thousand of Tons)					
	JOWAR	GRAM	RAPESEED & MUSTARD	TOBACCO	BARLEY	MUNG
1955	6.61	19.54	6.16	1.87	3.11	0.71
1956	7.38	20.09	6.32	1.20	3.76	0.62
1957	5.54	18.41	6.53	1.32	3.18	0.54
1958	6.11	16.22	6.18	1.32	3.65	0.56
1959	6.57	17.27	7.41	1.50	4.66	0.66
1960	6.11	16.88	6.23	1.56	4.22	0.59
1961	6.95	16.67	6.10	1.73	3.16	0.60
1962	7.24	19.54	9.17	1.95	3.16	0.52
1963	6.76	17.47	6.03	1.81	2.92	0.44
1964	7.68	19.40	5.11	2.16	3.07	0.62
1965	6.51	16.15	4.83	2.18	2.36	0.52
1966	7.19	18.62	6.68	3.11	2.27	0.62
1967	7.93	15.26	8.15	3.42	2.51	0.56
1968	7.68	14.73	6.45	3.45	2.63	0.63
1969	6.89	14.72	6.42	3.17	1.96	0.50
1970	8.19	13.79	6.77	2.95	2.75	0.61
1971	7.25	14.52	8.08	2.87	2.75	0.71
1972	7.10	15.37	7.51	2.35	2.56	0.67
1973	7.53	17.43	7.80	1.51	3.05	0.61
1974	6.54	15.47	6.82	1.80	2.96	0.66
1975	7.02	17.13	7.28	1.78	2.94	0.67
1976	6.58	18.36	7.75	1.59	2.72	0.57
1977	6.17	16.78	6.46	2.03	2.56	0.64
1978	5.95	15.81	6.50	2.07	2.86	0.53
1979	6.15	9.78	6.75	1.74	2.63	0.68
1980	5.69	9.88	6.78	2.03	3.89	0.64
1981	5.50	7.87	6.33	1.91	3.53	0.59
1982	5.47	13.50	6.59	1.74	3.60	0.75
1983	5.28	14.08	5.68	1.78	2.78	0.78
1984	5.65	14.22	6.06	2.16	2.29	0.88
1985	5.40	15.88	6.76	2.94	2.38	0.99

Table B.1: Output and Input Quantities by Year (concluded)

YEAR	INPUTS					
	FERTILIZER (Thousand Tons)			LABOR (000 Units)	ANIMAL LABOR (000's)	TRACTORS (Units)
	NITROGEN	P_2O_5	K_2O			
1955	-	-	-	44,601.8	135.7	80
1956	-	-	-	45,614.0	136.9	84
1957	-	-	-	46,626.3	138.1	88
1958	-	-	-	47,638.5	139.2	92
1959	-	-	-	48,650.8	140.4	97
1960	-	-	-	49,663.1	141.5	103
1961	-	-	-	50,675.3	144.2	126
1962	-	-	-	50,887.5	146.9	148
1963	-	-	-	51,099.8	149.5	172
1964	-	-	-	51,312.1	152.2	199
1965	2.09	0.04	-	51,524.3	154.8	225
1966	3.13	0.12	0.003	51,736.5	157.5	309
1967	4.95	0.36	0.006	51,948.8	160.1	393
1968	5.70	1.09	0.062	52,161.1	162.8	477
1969	7.90	0.96	0.030	52,373.3	165.4	557
1970	7.58	0.92	0.030	52,585.6	168.1	637
1971	9.77	1.06	0.019	52,797.8	170.7	717
1972	10.92	1.39	0.037	53,010.0	173.4	786
1973	9.78	1.67	0.072	53,222.3	170.8	850
1974	10.29	1.73	0.058	55,345.7	168.2	924
1975	12.55	2.95	0.083	57,469.1	165.7	994
1976	14.47	3.33	0.071	59,592.4	163.1	1293
1977	15.53	4.46	0.165	61,715.8	161.0	1578
1978	19.22	5.29	0.130	63,839.1	158.8	1870
1979	22.91	6.45	0.262	65,962.5	156.7	2170
1980	22.85	6.39	0.275	68,085.9	154.5	2470
1981	23.42	6.36	0.590	70,209.2	152.3	2740
1982	26.59	7.46	0.700	72,332.6	150.2	3100
1983	25.62	7.30	0.820	74,456.0	148.1	3750
1984	26.19	8.83	0.710	76,579.3	145.9	4300
1985	32.99	9.82	0.930	78,702.7	143.8	4750

Table B.2: Output, Input, and TFP Indexes for Pakistan

YEAR	OUTPUT INDEXES			INPUT INDEXES			TFP INDEXES		
	LASP	F-C	TQ	LASP	F-C	TQ	LASP	F-C	TQ
1956	94.15	97.04	95.57	96.87	97.05	97.16	97.30	97.04	98.44
1957	97.39	97.13	97.75	98.35	98.32	98.36	99.02	98.76	99.37
1958	104.02	103.83	104.00	100.69	100.67	100.65	103.31	103.14	103.32
1959	100.78	100.93	100.28	101.61	101.57	101.52	99.18	99.35	98.76
1960	103.64	104.00	102.39	102.47	102.38	102.30	101.16	101.60	100.13
1961	111.50	112.07	109.58	104.88	104.78	104.64	106.39	107.04	104.85
1962	123.54	124.12	120.36	106.29	106.12	106.33	116.43	116.90	113.65
1963	121.45	122.16	117.49	107.20	107.12	106.79	113.30	114.09	110.07
1964	128.87	129.97	124.24	109.03	109.01	108.69	118.24	119.22	114.46
1965	127.06	127.54	120.07	110.19	109.59	110.79	114.93	115.93	107.90
1966	132.64	134.29	132.64	113.13	112.28	113.47	116.85	119.16	109.59
1967	152.80	157.44	139.18	116.97	115.94	117.15	130.44	135.52	118.08
1968	169.99	175.09	155.02	142.12	147.39	128.69	119.12	118.08	119.33
1969	185.82	190.77	166.74	121.20	119.74	120.99	152.26	157.81	135.93
1970	173.86	179.04	156.67	122.23	120.76	122.01	141.34	146.94	126.51
1971	181.41	188.69	165.03	124.59	122.72	123.97	144.45	152.11	131.06
1972	188.21	194.01	168.77	147.77	154.12	132.03	126.61	124.73	125.97
1973	200.81	208.20	179.10	127.22	125.84	127.02	157.69	164.62	139.37
1974	190.83	195.86	166.10	128.42	127.29	128.46	148.62	153.18	127.69
1975	206.05	211.96	178.91	132.89	131.89	133.01	155.24	160.25	133.12
1976	215.82	222.05	186.84	139.42	138.47	139.43	154.57	159.48	132.27
1977	222.07	230.19	192.51	144.39	143.20	144.07	153.29	159.55	131.72
1978	228.06	233.57	195.34	150.65	148.87	149.60	151.43	156.12	128.79
1979	246.62	253.82	210.06	157.46	154.51	155.14	156.86	163.16	133.29
1980	256.13	267.07	220.21	161.06	157.92	158.52	159.21	167.77	136.52

YEAR	OUTPUT INDEXES			INPUT INDEXES			TFP INDEXES		
	LASP	F-C	TQ	LASP	F-C	TQ	LASP	F-C	TQ
1981	272.03	281.94	231.42	165.90	162.73	163.91	164.11	171.64	139.23
1982	282.35	297.33	240.91	172.23	167.81	168.23	164.51	175.68	140.80
1983	249.54	258.55	205.68	178.79	173.12	173.37	141.96	149.93	118.31
1984	271.44	292.33	229.24	184.66	177.96	178.12	147.19	161.88	126.21
1985	284.27	308.74	240.97	193.50	183.59	183.62	147.17	165.39	128.27

Note: LASP = Laspeyres; F-C = Fisher-Chained; TQ = Tornqvist

Table B.3: TFP Indexes for Selected Provinces of **Pakistan**

YEAR	PUNJAB		SIND		NWFP	
	F-C	TQ	F-C	TQ	F-C	TQ
1956	97.41	98.64	98.12	99.86	94.07	95.47
1957	96.77	97.21	102.18	103.27	99.39	99.72
1958	103.02	102.79	105.15	106.27	100.16	100.09
1959	100.91	100.46	94.02	93.30	103.29	102.45
1960	101.76	100.80	100.79	97.86	102.44	101.76
1961	107.14	105.45	106.52	102.75	107.58	106.41
1962	119.38	116.53	115.40	110.42	111.53	109.90
1963	114.07	110.81	113.52	107.68	115.08	111.69
1964	121.37	117.62	116.99	110.53	116.18	111.01
1965	108.04	100.21	123.71	114.27	127.89	121.65
1966	117.46	107.67	120.32	110.82	122.89	113.63
1967	143.77	127.85	131.36	119.32	116.31	85.11
1968	150.54	133.74	150.91	134.09	131.58	103.69
1969	158.91	140.68	176.82	154.13	122.66	90.53
1970	142.83	125.20	176.85	154.24	110.49	84.41
1971	147.32	129.15	183.89	159.50	114.31	89.68
1972	147.54	128.55	188.32	163.03	117.97	91.34
1973	156.19	135.81	197.09	170.27	137.21	99.17
1974	151.22	130.90	165.79	138.45	138.38	99.59
1975	158.47	136.56	179.33	149.02	134.07	95.69
1976	157.22	135.81	180.25	149.76	130.09	91.94
1977	153.75	131.67	186.44	154.22	133.07	94.36
1978	154.96	132.62	176.40	145.92	125.99	89.73
1979	157.44	132.62	202.21	165.18	116.18	82.28
1980	166.43	139.68	205.91	166.67	108.45	76.27
1981	162.09	136.32	225.15	180.52	112.68	79.60
1982	166.04	137.90	224.92	178.77	124.12	86.70
1983	135.15	110.07	195.60	154.87	120.62	83.50
1984	156.23	124.01	201.31	158.21	114.03	79.83
1985	169.39	133.15	188.03	147.65	115.00	80.49

Note: F-C = Fisher-Chained Index; TQ = Tornqvist Index

APPENDIX C

Statistical Sources and Variable Descriptions

This appendix describes the variables used in the data set for this study. It describes their sources, units of measurement, and any necessary transformations.

C.1 Coverage

We covered all of the districts in Sind, Punjab, and the NWFP. These three provinces constitute the bulk of agricultural production in Pakistan. As far as possible, we used the original districts as they existed within their boundaries in 1955. Any new district created since was included in the parent district. This was done in order to maintain consistency among the observations and to allow meaningful comparisons through time. The districts that existed in 1955 are our observational units.

Each district was assigned a unique identification code in the data set. The code consists of a one-digit province identification number, which is the variable STATE, and a two-digit district number called DISTRICT. This classification system is summarized in Table C.1. It can easily be determined that the code 1 01 represents Attock, while 2 01 represents Khairpur. Combining these two variables, we create STDIST, which is a three-digit identification code, where Attock is represented by 101. The district of Karachi has been excluded from consideration due to its lack of agricultural production. Rawalpindi includes the present Islamabad district.

The data set covers agricultural production from the year 1955-56 to 1985-86, which is the last year for which we were able to obtain data. The variable YEAR stores a two-digit code indicating the calendar year of the observations.

Table C.1: State and District Identification Codes

	PUNJAB (1)		
Attock (01)	Jhang (11)	Sahiwal (19)	Rawalpindi (02)
Mianwali (12)	Multan (20)	Jhelum (04)	Sialkot (14)
Muaffargarh (22)	Gujrat (06)	Gujanwala (15)	D.G. Khan (24)
Sargodha (07)	Sheikhupura (16)	Bahawalapur (28)	Faisalabad (09)
Bahawalnagar (29)	Lahore (17)	R.Y. Khan (30)	
	SIND (2)		
Khairpur (01)	Nawabshah (05)	Tharpakkar (08)	Thatta (12)
Jacobabad (02)	Larkana (06)	Dadu (09)	Sukkur (03)
Sanghar (07)	Hyderabad (10)		
	NWFP (3)		
Peshawar (01)	Abbottabad (05)	D.I. Khan (10)	Mardan (02)
Hazara (08)	Kohat (03)	Bannu (09)	

Table C.2: Crop Variables

Variable	Coverage
WHEAT	Total wheat
RICE	All rice, regardless of type
COTTON	All cotton, regardless of type
SUGAR	Refined sugar
BAJRA	
MAIZE	
JOWAR	
GRAM	
RAPEMUS	Rapeseed and mustard
TOBAC	Tobacco
BARLEY	
MUNG	
MAXWHT	High-yield varieties of wheat
BASRCE	Basmati rice
IRRIRCE	IRRI improved varieties of rice
PAKCTTN	Pak Upland cotton
DESCTTN	Desi or local cotton

C.2 Outputs

The data set contains data on the prices and quantities harvested of 12 major Pakistani crops. These crops are listed in the following table.The variables listed in the second panel of Table C.2 represent sub-varieties and improved varieties of the basic crops listed in the first panel.

As it is also necessary to distinguish between prices, quantities, and yields, the following notational conventions have been used. To represent a quantity, the prefix Q is attached to the variable name. Thus QGRAM represents the quantity of gram produced, measured in thousands of metric tons. The source of these data is the Agricultural Statistics of Pakistan, except for the year 1968. For that year, quantities were estimated for about half of the crops since the data was not available.

To represent output prices, the prefix P is attached to the variable name. Because of inconsistencies, wholesale prices from the Statistical Yearbooks are used rather than farm-gate prices. Wholesale prices are only available for certain key markets over the time period under investigation. These key markets are:

	SIND	
Sukkur (203)	Hyderabad (210)	Karachi (213)
	PUNJAB	
Sargodha (107)	Lahore (117)	Multan (120)
Faisalabad (109)	Rawalpindi (102)	

Each district was assigned to a market on the basis of distance. This market provided the output prices. The code for the market is the same as the state-district identification code (STDIST). The variable is called MARKET and its possible values are given above with the market names.

The prefix Y indicates the yield of a given crop, calculated as quantity divided by area planted. Thus, for example, YDESCTTN indicates the yield of Desi cotton. The prefix YI before a crop name indicates the yield index. For example, YIGRAM is the yield index for gram. The yield index is normalized by the average for the first three years of the series, which in this case means

1955, 1956, and 1957. This average is the base of the index and is set equal to 1.0. Thus an index number of 2.0 indicates that the crop's yield in that particular year was twice the average of the first three years.

Finally, an aggregate output variable was constructed, using prices as the weights. The variable QCROPS is a weighted index of output quantities. PCROPS is an aggregate index of output prices, normalized to unity in the first year.

C.3 Inputs

Five factors of production have been considered; land, labour, tractors (mechanization), animal power, and fertilizer. For each variable, the data set includes observations on prices and quantities, by year and district.

The land data comes from various editions of the Agricultural Statistics of Pakistan, measured in thousands of hectares. The variable is denoted by the prefix A attached to the crop name. Thus ARICE is the area under rice cultivation. As there are virtually no data on the value of land, the price of land was set equal to 30% of the total input costs. While this is not the true value, based on our evidence we believe this to be a good approximation.

There is no single annual source reporting the number of farm laborers at the district level. It was therefore necessary to estimate this figure from two sources. The variable QLABOR represents the number of agricultural workers reported in the 1951, 1961, and 1981 Population Censuses. Since the 1972 Population Census data were not available, the Agricultural Censuses were used for comparison. The agricultural labor force from these 1972 and 1980 censuses, measured in thousands, is given by the variable AGLABOR. Interpolation is used to fill in the missing years. For each district, the ratio of the Agricultural Census workforce to the Population Census workforce was determined for the year 1980. This ratio was then imposed on the 1972 Agricultural Census to create a hypothetical 1973 Population Census. The missing observations of QLABOR were then found by interpolation.

There is also little direct data on agricultural wages. We do have the following estimates of daily wages in 1983-84 for selected districts, from a cost of production study.

Sargodha	20.5	Sahiwal	16.8	Sheikhupura	20.0
R.Y. Khan	22.5	Hyderabad	23.3	Sukkur	23.0

These wages were imposed throughout each of the districts' divisions, using the boundaries in effect in 1955. An index based on ILO data and industrial wages was used to adjust the wages over time. We assumed that laborers worked 188 days per year.

Our data on the tractor stock came from a variety of sources. When district level data was available, it was used directly. When only provincial data existed, we estimated the share of each district from different years. When no data was available, interpolation was used to fill in the missing values of QTRACTOR.

1955	8	1962	8	1969	10	1976	30	1983	100
1956	8	1963	10	1970	12	1977	36	1984	170
1957	8	1964	12	1971	13	1978	40	1985	170
1958	8	1965	11	1972	13	1979	45		
1959	8	1966	11	1973	23	1980	53		
1960	9	1967	9	1974	32	1981	78		
1961	9	1968	10	1975	30	1982	80		

The wholesale price of a 47hp tractor from the Statistical Yearbooks was used when available. This is a typical tractor in Pakistan. An index using FAO data was constructed to project the price into the past. These prices are reported in PTRACTOR. After we had determined the value of the tractor stock for each year, these values were scaled by the factor 0.25 to approximate annual expenditures on tractors.

Concise data on animal labor is only available for the few years in which an Agricultural Census or a Livestock Census was carried out. Straight interpolation was used to fill in the values of QANLAB for the intervening years.

An estimate of bullock prices was made for 1981. Using this and the price of maize, an index was computed for the estimated price of animal labour, called PANLAB. As with tractors, the value of the animal workforce was determined and scaled by a factor of 0.50 to estimate annual expenditures on animal labor.

District level data on fertilizer dates back to 1978. From 1965 to 1977, numbers are only available at the provincial level, so the average district shares were imposed on these provincial totals. The fertilizer types included in the study are NITRO, P2O5, and K2O. The Q prefix indicates metric tons of each nutrient. Fertilizer prices are set by the government and were obtained from official sources. The prefix P indicates the price per nutrient metric ton, measured in rupees.

Once the input prices and quantities had been estimated, aggregate input quantity and price indexes were constructed. QINPUT is the input index, where input prices are used as share weights. PINPUT is the aggregate input price index. Both indexes are normalized to unity in the year 1955. The variables SHFERT, SHLABOR, SHTRAC, SHANLAB, and SHLAND are the estimated cost shares for fertilizer, labor, tractors, animal labor, and land, respectively.

C.4 Infrastructure

A variety of sources reported irrigation by district in the Punjab, but there were fewer sources for Sind and NWFP. Linear interpolation was used to fill in the missing data. Road length data were reported in the Statistical Yearbooks of Pakistan and in the Road Transport Statistics. Data on the average distance to market were obtained from Village and Mauza Statistics.

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