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YALE UNIVERSITY

Box 1987, Yale Station
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AGRICULTURAL RESEARCH PRODUCTIVITY IN PAKISTAN

Qazi Tauqir Azam
Pakistan Agricultural Research Council, Islamabad

Erik A. Bloom
Yale University

Robert E. Evenson
Yale University

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Erik Bloom is a Ph.D. candidate in the Economics Department at Yale University.

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			ANIMAL RESEARCH		
	1972-75	1976-79	1980-83	1972-75	1976-79	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	Baluch istan	USA	Austr alia	Bei rut	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	Fed-eral
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

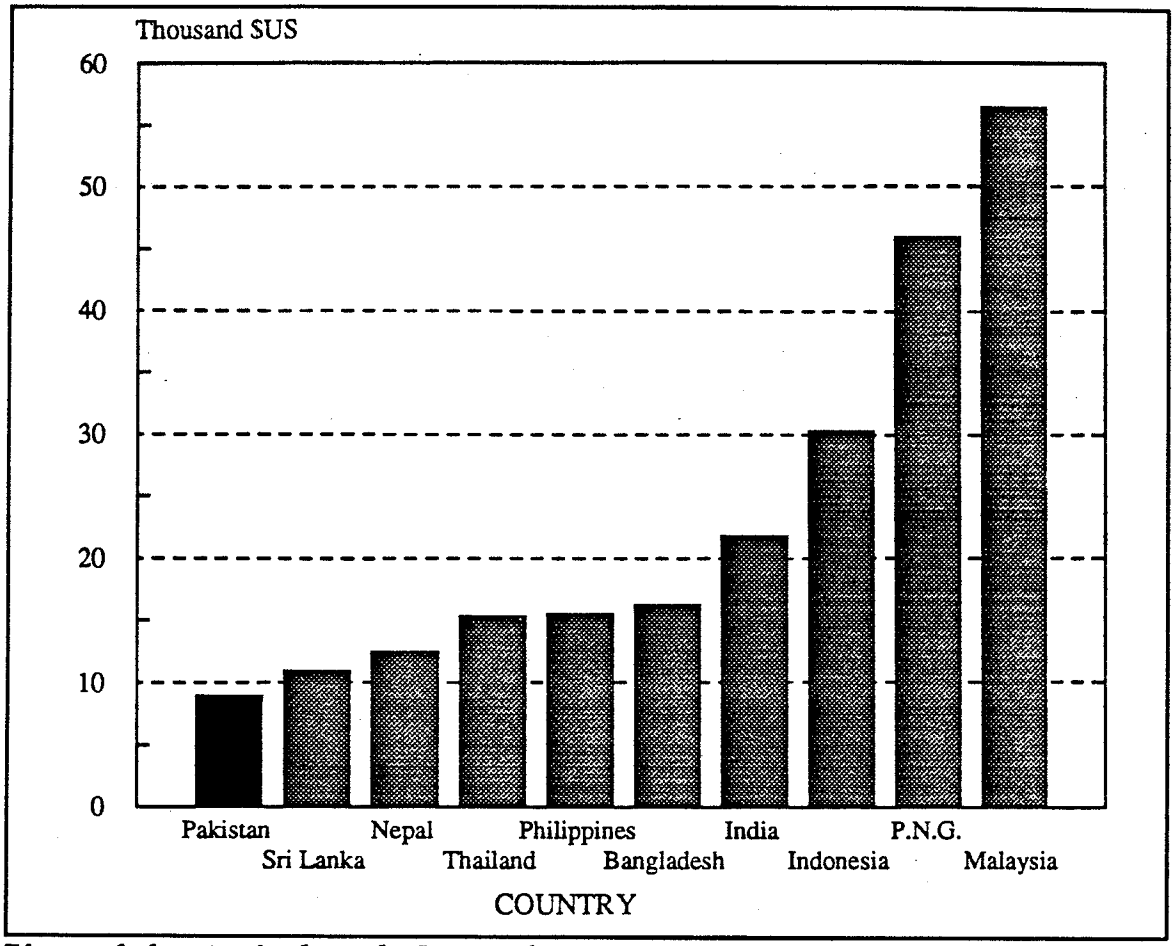

Figure 1.1: Agricultural Research Expenditures per Scientist (Selected Countries in Asia, 1980)

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.

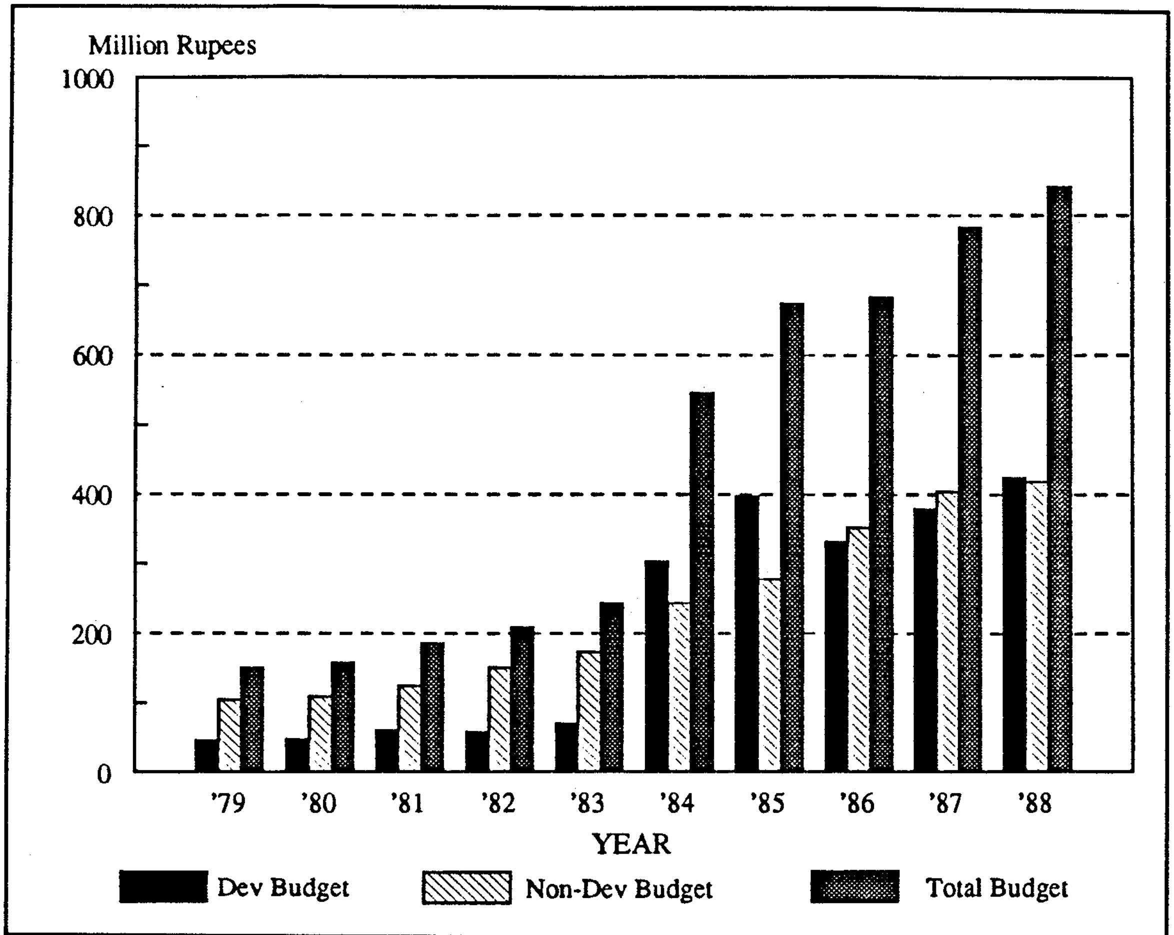

Figure 1.2: Development and Non-Development Budget of 50 Agricultural Research and Education Establishments

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.

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

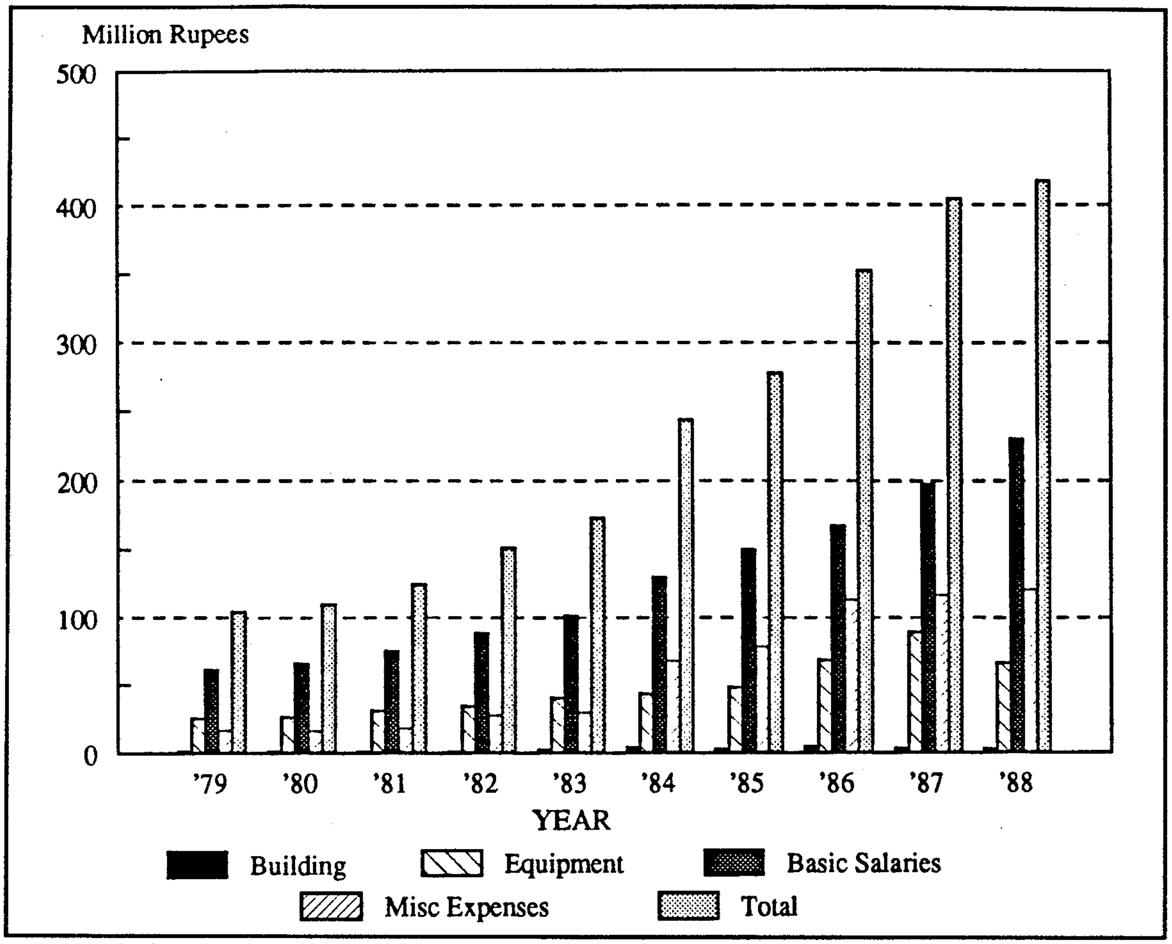

Figure 1.3: Non-Development Budget of 50 Agricultural Research and Education Establishments

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.

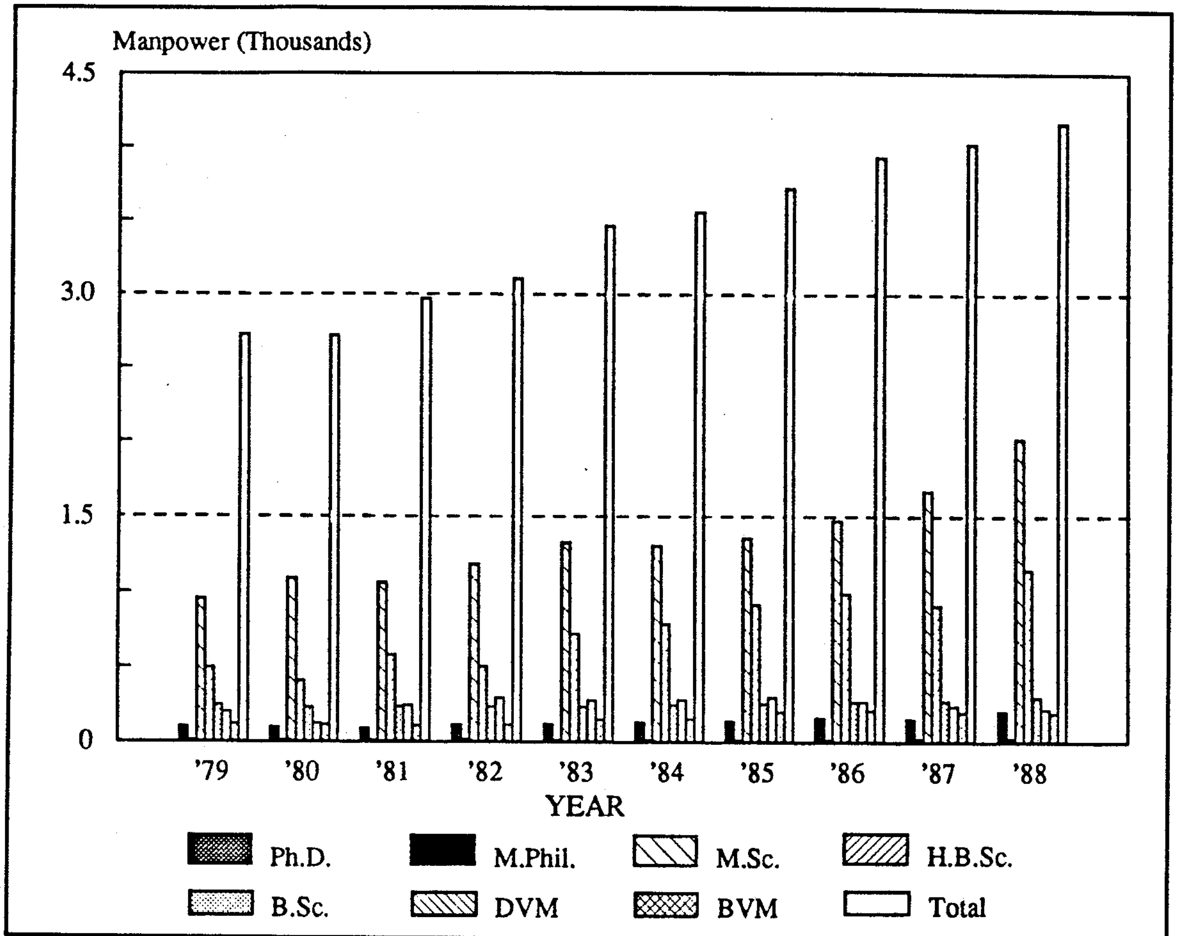

Figure 1.4: Trained Manpower in 50 Agricultural Research and Education Establishments

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.

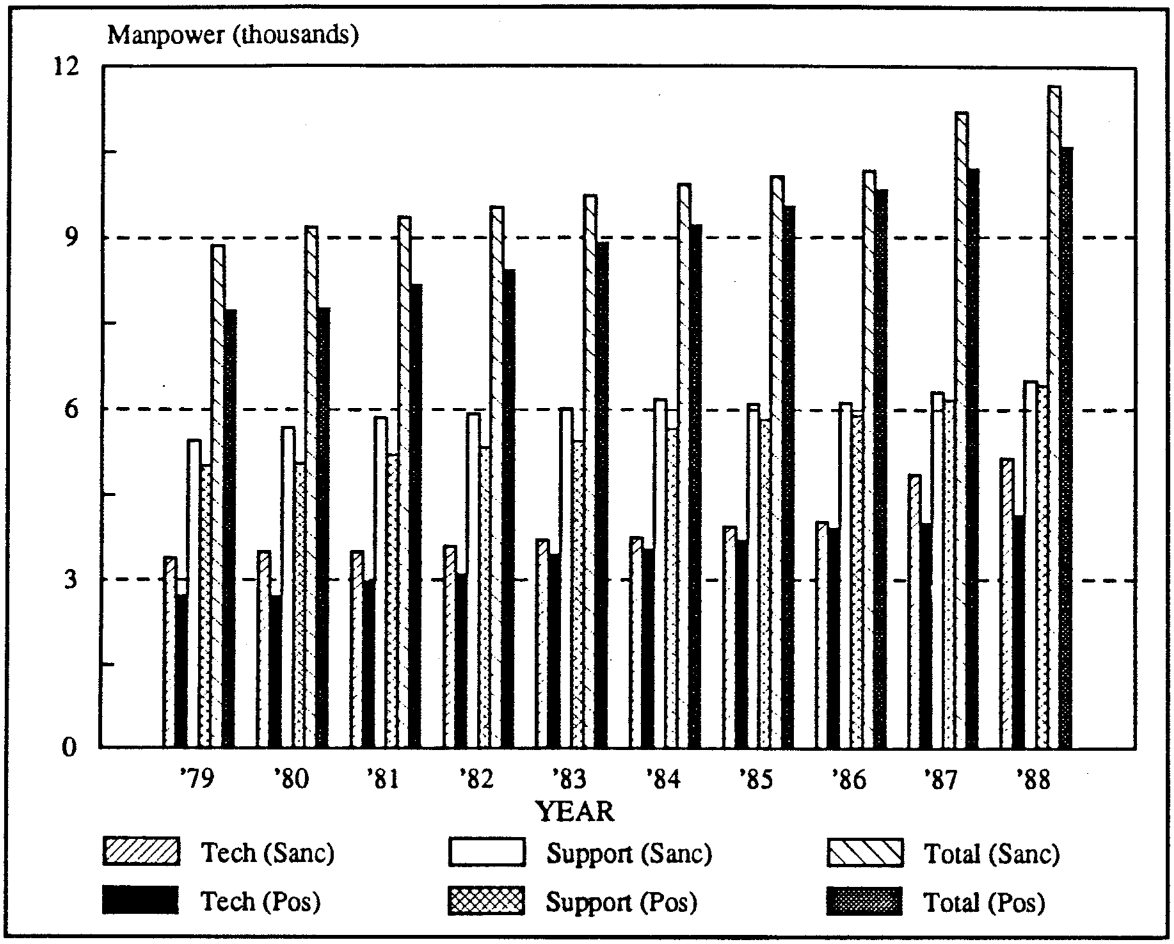

Figure 1.5: Sanctioned Staff Levels and Positions Filled in 50 Agricultural Research and Education Establishments

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.

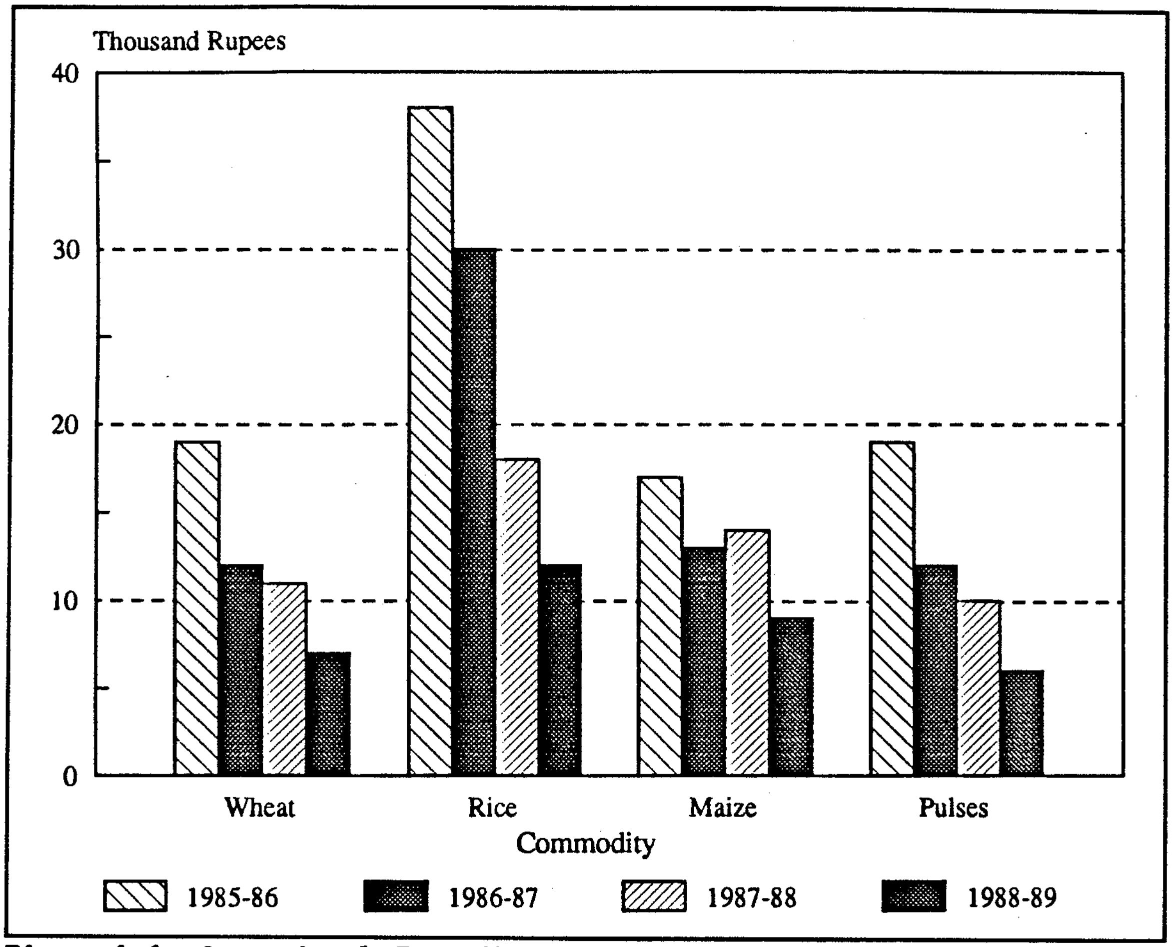

Figure 1.6: Operational Expenditure per Scientist for Selected Research Programs (NARC)

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

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[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:

$$\sum_i P_i Y_i = \sum_j R_j X_j, \qquad (2.1)$$

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:

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

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.

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

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

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:

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

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 $T^* = R^* - P^* = (R/P)^*$. 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:

$$\frac{dY}{Y} = \sum_j C_j \frac{dX_j}{X_j}, \qquad (2.7)$$

where C_i is the cost share for the jth 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, $\dot{T}$, as:

$$T^* = Y^* - \sum_j C_j X_j^* = Y^* - X^*. \qquad (2.8)$$

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 $\dot{T}$ 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):

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

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

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

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.