# High Economic Returns from Investment in Agricultural Research

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Summary of a study on "Agricultural Research Productivity in Pakistan" by Qazi Tauqir Azam, Robert E. Evenson and Erick Bloom. This summary has been written by Steven A. Breth.

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# FOREWORD

Those of us who do agricultural research know that research is vital to agricultural development and that money invested in agricultural research pays rich returns. With this publication researchers now have quantitative data to support our arguments. This report is a summary of a comprehensive research project done by PARC and Yale University (U.S.A.) economists. The full account of this study is being separately published as a PARC Technical Report.

This study points out that investment in agricultural research in Pakistan has paid enormous returns, that research is a low-cost source of economic growth in Pakistan, and that Pakistan has under-invested in its agricultural research program. In fact the authors emphasize that investments in agricultural research are currently so low in Pakistan that the entire research system is endangered.

Thanks are due to Mr. Steven Breth of Winrock International who prepared this summary and to Directorate of Publications, PARC, which published this attractive and easily readable paper. Finally, I wish to thank all those persons in the Provinces who rendered their cooperation and assistance in providing the data upon which this study is based.

(Dr. Zafar Altaf)
Additional Secretary,
Agricultural Research Division,
and Chairman, Pakistan Agricultural
Research Council, Islamabad

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# High Economic Returns from Investment in Agricultural Research

## INTRODUCTION

Pakistan is at a critical point in its development. Its population is growing rapidly, as is its demand for food. *Population will increase 50% to 148 million within a decade.* At the same time, agricultural growth is being restrained by drought, increase in saline and waterlogged soils, and the varied climate and topography of the country. Opportunities to expand onto productive soil or to extend irrigation under favourable conditions have already been exploited.

Historically, countries that have exhausted their low-cost options for land expansion have turned to productivity expansion options as a means of raising agricultural production. Improvements in agricultural technology and farmer efficiency as a result of research and extension programmes have been important sources of productivity change in most countries. Three economists, Qazi Tauquir Azam of Pakistan Agricultural Research Council, Erick Bloom and Robert Evenson of Yale University recently completed a study of agricultural research productivity in Pakistan*. They found that *between 1958 and 1985 agricultural research had an exceptionally high payoff for the nation.* But they also found that *current budget cutting is in danger of stifling the research system.*

## GROWTH IN PAKISTAN'S RESEARCH CAPACITY

The authors documented the growth of Pakistan's research capacity since 1958 and compared it with growth in other countries. For their study, they analyzed the research budgets and scientific staffing of 64 research centres and institutions in Pakistan, including the major provincial and federal institutions.

By 1960, they found, Pakistan was rapidly building agricultural research institutions. The ratio of research expenditures to value of agricultural

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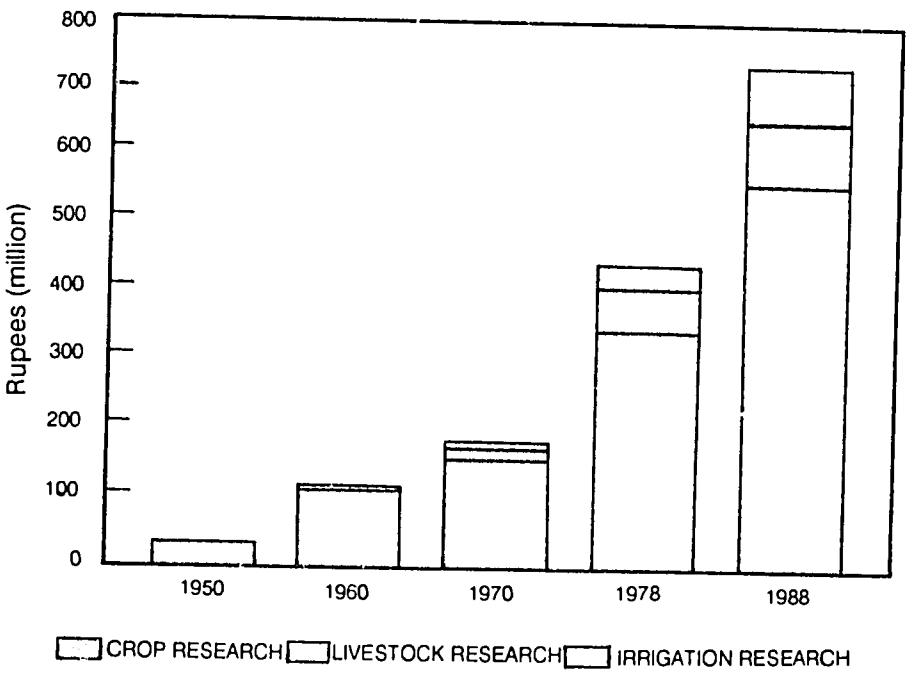
**Qazi Tauqir Azam, Robert E. Evenson and Erick Bloom. Agricultural Research Productivity in Pakistan (Islamabad: Pakistan Agricultural Research Council, 1991).*

products was higher in Pakistan than in other South and Southeast Asian countries. Pakistan continued to expand in 1960s and 1970s but not as fast as other countries of the region. By the 1980s the *ratio of research expenditures to value of production in Pakistan was 0.5 percent*, about the same as other low-income countries of region. But the *ratios in Thailand, Taiwan, South Korea, and Malaysia had reached over 1 percent.*

**Figure 1. Agricultural Research Expenditures in Pakistan (Deflated)**




(Million Rupees)

| Year | Crop Research | Livestock Research | Irrigation Research |
|---|---|---|---|
| 1950 | 33.52 | 0.00 | 0.00 |
| 1960 | 104.96 | 6.23 | 0.00 |
| 1970 | 148.74 | 18.60 | 4.87 |
| 1978 | 338.19 | 59.97 | 33.44 |
| 1988 | 552.00 | 105.00 | 85.00 |

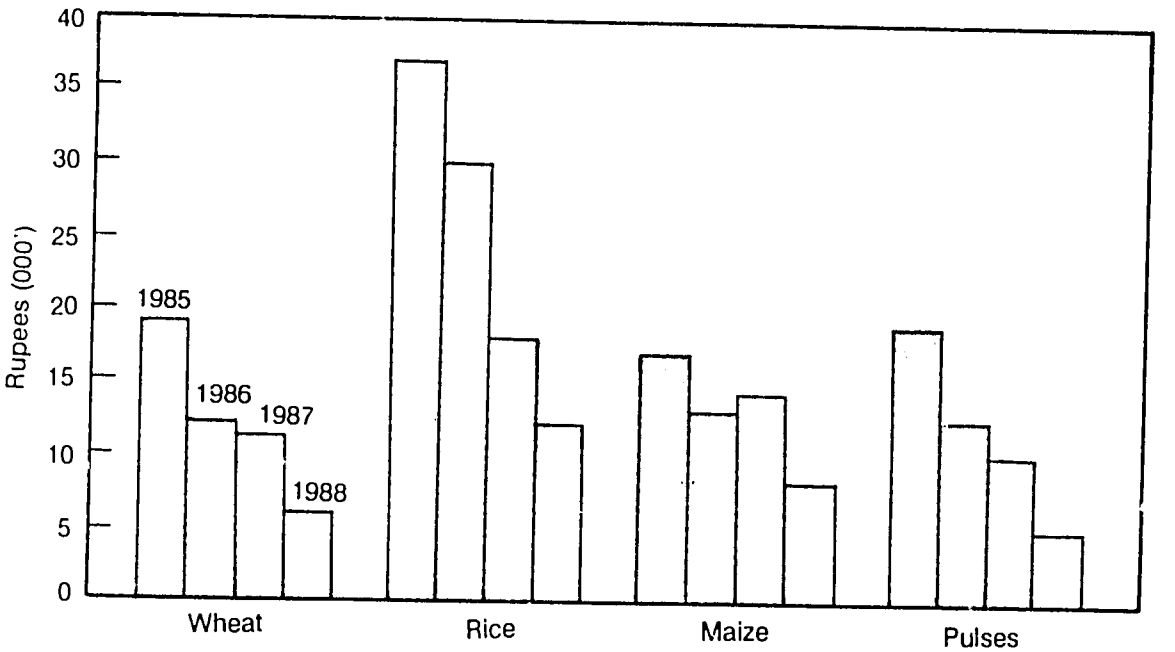
During this four-decade period, Pakistan had an exceptionally low level of expenditure per scientist. Moreover, recently, *operational research funding*

*per scientist has dropped to very low levels compared with other countries.*

There are two critical implications for policy makers:

- Research resources in Pakistan are available at bargain prices by international standards.
- Low expenditures per scientist reflect cost-cutting measures that may now be so severe that they threaten to cripple the effectiveness of the research system.

**Figure 2. Operational Expenditure per Scientist in Pakistan (Selected NARC Research Programmes 1985-1988)**




(000, Rupees)

| Year | Wheat | Rice | Maize | Pulses |
|---|---|---|---|---|
| 1985 | 19 | 37 | 17 | 19 |
| 1986 | 12 | 30 | 13 | 12 |
| 1987 | 11 | 18 | 14 | 10 |
| 1988 | 6 | 12 | 8 | 6 |

## CHANGE IN AGRICULTURAL PRODUCTIVITY

To assess agricultural productivity trends in Pakistan, the authors analyzed data for each major agricultural district in the Sindh, Punjab, and

Northwest Frontier provinces from 1956 to 1985. They computed two productivity indexes to measure changes: yield (called partial factor productivity) and aggregate production per unit of aggregate input (called total factor productivity).

Crop yield is called partial factor productivity (PFP) because it relates output only to land, which is just one of the inputs influencing output, but probably the most important one. Its weakness is that it is affected by the level of use of other inputs. Hence it is a crude efficiency measure.

The economists computed yield indexes for sugarcane, maize, bajra, jowar, wheat, rice, cotton, barley, gram, and mung. In the pre-green revolution period, 1965-66, the highest rates of yield change were in cotton, mung, rice, and bajra. All three provinces had rapid yield growth in these crops. In the green revolution period, 1967-72, rice and wheat outstripped all other crops in yield increases, though cotton and barley also showed substantial yield gains. In the post-green revolution period, 1972-85, only wheat continued to improve in productivity at high rates.

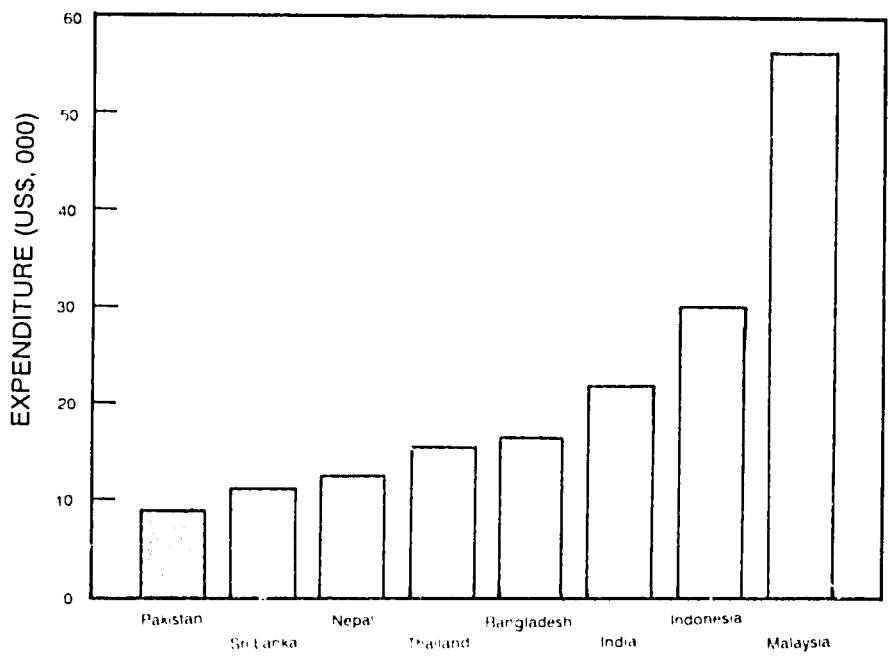
Total factor productivity provides a different vantage point on Pakistan's productivity changes. While TFP does not permit commodity specific detail, it takes account of such inputs as labour, fertilizer, and mechanical and animal power as well as land. That makes it a good general efficiency measure.

TFP can be given two interpretations. First, if input use is held constant, TFP change measures the added production obtained from one period to the next. Second, if prices are held constant, TFP change measures the rate of reduction in the cost of producing a unit of product.

The total factor productivity for the above 10 crops, plus tobacco, and rapeseed and mustard seed was computed. To provide an international comparison, TFP was also calculated for the State of Punjab in India. In the pre-green revolution, TFP grew 1.7 to 2.7 percent a year in the three Pakistan provinces and the Indian Punjab. These rates of productivity growth are considered moderate. In the green revolution period. productivity in the Sindh grew by over 5 percent annually, in the Pakistan Punjab it grew by 2 to

3 percent, and in NWFP it had zero or negative growth. Efficiency growth in the Indian Punjab was comparable to that of the Sindh. In the post-green revolution period, the growth in the Sindh was low to modest, growth in Pakistan Punjab fell below the pre-green revolution rates, growth in NWFP continued to be negative. The Indian Punjab had better performance than any of the three Pakistan provinces. Overall, the Sindh and the Indian Punjab outperformed the Pakistan Punjab, with the chief differences occurring in the post-green revolution period.

**Figure 3. Agricultural Research Expenditure per Scientist in Selected Countries - 1980**




| Country | Expenditure (US $, 000) |
|---|---|
| Pakistan | 8.9 |
| Sri Lanka | 10.9 |
| Nepal | 12.4 |
| Thailand | 15.3 |
| Bangladesh | 16.2 |
| India | 21.8 |
| Indonesia | 30.2 |
| Malaysia | 56.4 |

## CAUSES OF DIFFERENCES IN GROWTH

Having established that significant changes in farm productivity have occurred in Pakistan, the authors analysed the contribution of agricultural research to these changes. Their aim was to determine whether Pakistan invested too much or too little in research, that is, did Pakistan taxpayers receive good value for the money invested in research?

To do so, they estimated returns on investment that could be compared with returns on investment in irrigation, roads, and other activities that produce growth in agricultural production. This analysis is highly complex because of the myriad influences that shape productivity. Weather and incidence of insects and diseases influence production in different years. The quality of agricultural infrastructure--irrigation systems and roads--affect productivity because they provide services to agriculture that are not counted as inputs. Also new technology from other countries may by adopted or adapted.

The authors analysis included measures to account for irrigation, road density, market distance, adult male literacy (human capital), time lags between research expenditures and productivity changes, and the introduction of technology from abroad.

Among their findings were that infrastructure--expanded irrigation and better farm markets--significantly contributed to productivity growth. Educational level of farmers also had a strong influence on productivity growth.

For agricultural research, both applied and general research propelled productivity growth. Districts that were provided with more research services attained better productivity growth. Yet, investment in research does not pay off immediately. The economists' analysis showed that for applied agricultural research, the impact on productivity began 5 years from the time the research expenditure was made, and the full impact was realized after 10 years. For more general research, including animal research, the time lag was a year longer.

## RETURNS ON INVESTMENT-OVERALL PRODUCTIVITY

The data provided strong evidence of profitability of agricultural research. The authors calculated the marginal products of research investment, that is, the amount of added output that would be eventually realized from

investing one additional rupee in research, and they found very high level:

| | *Return eventually realized from one rupee invested* |
|---|---|
| Applied research (excluding high yielding varieties) | 7.0 to 7.4 |
| High yielding variety research | 5.1 to 5.5 |
| Applied and high yielding variety research | 20.9 |
| General research | 10.2 |
| All agricultural research | 10.7 to 11.0 |

**RETURNS ON INVESTMENT-CROP SPECIFIC**

To separate the effects of research from those of other inputs-- fertilizer, tractors, labour, and animal power-- in their impact on the productivity of seven major crops, the authors employed a two-stage statistical process.

*Wheat, rice, and cotton, all yielded exceptionally high marginal products to investment.* These crops have benefitted from strong and sustained varietal improvement activities. For rice, both applied research and high yielding variety research had significant impact. For wheat and cotton, high yielding variety research had far more impact than other types of research. In addition, the analysis revealed significant effect for applied research on bajra, jowar and maize. Only for sugarcane was there no impact of research. *The return from investing one additional rupee in research was*:

| | *Return eventually realized from one rupee invested* |
|---|---|
| Bajra | 3.1 to 3.4 |
| Jowar | 4.2 to 5.4 |
| Maize | 3.7 to 3.9 |
| Coarse cereals | 3.5 to 4.1 |
| Rice | 22.4 to 27.3 |
| Wheat | 16.5 |
| Combined cereals | 21.2 to 22.6 |
| Cotton | 43.5 |
| Sugarcane | none |
| All commodities | 26.3 to 26.6 |

The fact that research impacts were not found in all crops is unsurpris-

ing, according to the authors. Each crop represents its own set of problems and research opportunities and is influenced by its own set of outside factors. It is unrealistic to expect research programmes to have an identical impact on all commodities in all periods.

## IMPLICATIONS AND INTERNATIONAL COMPARISONS

The marginal product estimates and time lag estimates can be used to compute the common financial yardstick--estimated marginal internal rate of return to investment. That is the return realized by an investor who invests 1 rupee and then receives a payback of 0.2 times the marginal product in the 5th year, 0.4 times the marginal product in the 6th year, and the full marginal product in the 10th and succeeding years.

On this basis, the estimated *marginal internal rates of return to investment in agricultural research in Pakistan from 1956 to 1986 were*:

| | |
|---|---|
| Wheat research | 76% |
| Rice research | 84-89% |
| Maize research | 46% |
| Bajra research | 44% |
| Jowar research | 52% |
| All cereal research | 81-84% |
| Cotton research | 102% |
| Sugarcane research | n.s. |
| Applied research (excluding HYV) | 57-63% |
| Applied research (including HYV) | 82% |
| General research (excluding HYV) | 46% |
| General research (including HYV) | 56% |
| All agricultural research | 57-65% |

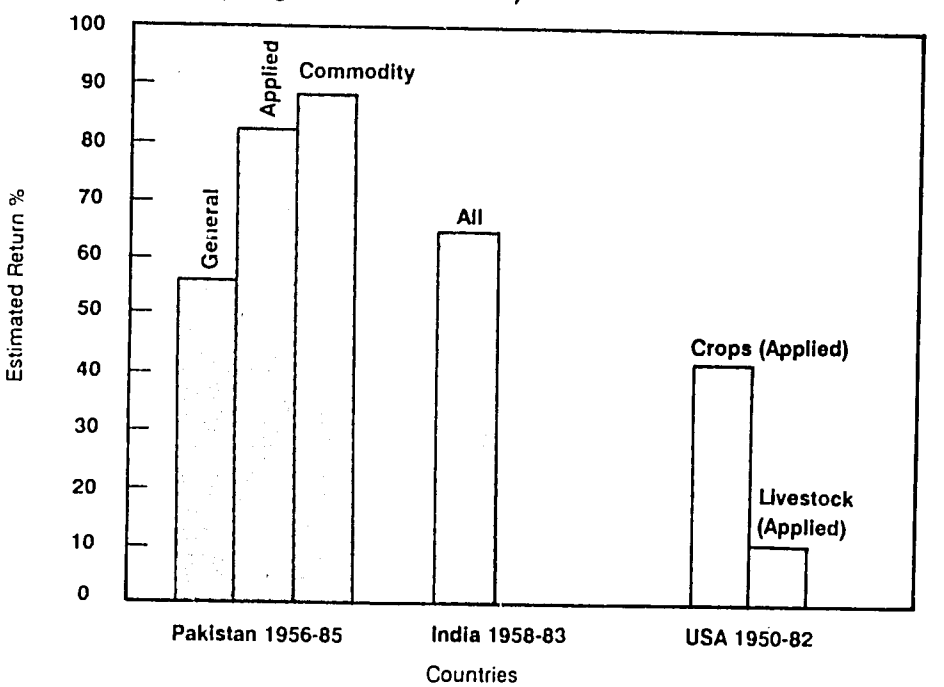
*These returns are far higher than the 10 to 15 percent return that would be considered good in public and private investments in Pakistan.* Even allowing for overestimation by a factor of 4 or 5, *these returns are much higher than other investments.* Thus, the authors observed that:

- Research has been a low-cost source of economic growth in Pakistan.
- Pakistan has not adequately exploited the rich returns possible from research and has underinvested in its research programme.

Research in Pakistan is a bargain, according to the authors , because it is low-priced as well as highly productive. If Pakistan had invested more in research, the estimated marginal products and rate of return would have been lower, but Pakistan would have gained because it would have achieved more low-cost growth than it did. *Comparison with other countries suggests that Pakistan could have productively invested at least twice as much in agricultural research as it actually did.*

In making future decisions, policy makers need to understand who benefitted from the productivity gains set in motion by agricultural research. The authors point to a number of studies that have demonstrated that most gains from increased productivity and food supply accrue to consumers through low prices. And poor households benefit most because food makes up a larger share of their total expenditures than it does for wealthier households.

**Figure 4. Annual Return on Research Investment in Pakistan, India and USA (Marginal rates of return)**




| | General | Applied | Commodity |
|---|---|---|---|
| Pakistan 1956-85 | 56 | 82 | 88 |
| India 1958-83 All | 65 | | |
| USA 1950-82 Crops (Applied) | 42 | 11 | Livestock (Applied) |

Among Pakistan's farmers, gains and losses depend on which district they are in. The poor performance of the NWFP districts poses a challenge for policy makers planning future research investments. Unless regional differences are redressed, regional disparities in farm incomes may worsen. Policy makers need to be mindful, however, that many factors other than research programmes are responsible for regional differences.

Future research programming will continue to require careful management reviews and project selection by research leaders. The burden will be on research leaders to continually evaluate Pakistan's project portfolio in relation to technological and scientific opportunities as well as to economic potential. Research leaders must stay abreast of advances in scientific knowledge and be aware of the economic size or number of economic units affected by individual research programmes.

The authors warn that the outlook for significant technological contributions from abroad, such as those that aided productivity gains in wheat, rice, and probably cotton during the past three decades is uncertain. Modern biotechnology, however, is a promising area that may ultimately produce considerable technology spill-in.

The authors conclude by stating that the *most critical short-term issue facing research leaders and policy makers today is the squeeze on salaries and inadequate support for research work. Short-sighted penny-pinching measures could seriously impair the research system.* If such problems had prevailed during the 30 years studied, the returns obtained would have been much lower. A good research system must support continued skill development and the maintenance and flow of new techniques and concepts.

In the decades since Independence, Pakistan has managed to expand food production in proportion to its growing population. It has done so by expanding both cultivated area and productivity. But the challenge ahead is severe. *In the next decade, Pakistan will have to rely on productivity gains alone to feed its growing population. To do so it will have to expand and strengthen its agricultural research system.*

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