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Agricultural Research Effort: Conceptual Clarity and Measurement

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Summary. — This paper emphasizes the need for basic conceptual clarity regarding the measures of research effort. In econometric analyses, this conceptual clarity could help reduce the misinterpretation of historical and institutional contexts underlying agricultural research effort. After a brief review of econometric studies estimating the returns to and determinants of research, the centrality of the conceptual, contextual and causal significance of this measure is examined. Conceptualized and measured at the input frontier of the research process, an expenditure measure of research reveals the institutional features and changes in the research process in India over time. This basic understanding is essential to develop appropriate econometric specifications and correspondingly effective research policy statements.

1. INTRODUCTION

Agricultural science is perhaps *the* science that has evolved in direct response to and simultaneously engendered revolutionary changes in the social, political, cultural and economic realms of human life. Among the vast array of subdisciplines (from chemistry, physics and biology to sociology and anthropology) that constitute agricultural science, economics alone denies the science its dynamic sociopolitical and cultural roots. While the importance of economics in agricultural science can never be questioned, we must not permit the discipline to use its assumptions and abstractions to gloss over the noneconomic constituents of agricultural science. In this paper the measure of agricultural research effort is chosen to prove that conceptual clarity and contextualization of the measure are central to our understanding of the science and the technology it generates. We highlight the need to understand the measure of research effort before using it to estimate returns to or determinants of research investment.

The estimation of returns to investment in agricultural research has, since the 1960s, become the major concern for several economists excelling in econometric analyses and interpretations.[1] More recently, there have also been estimates of the determinants of investment in agricultural research.[2] A problem of major conceptual significance evident in all these studies, is the lack of distinction between and consequent confusion about investment in research, research activity and research output. In less-developed countries facing a resource crunch, with inadequate articulation of demand for research from the client groups, high diversity and variability in agricultural production, and bureaucratized research systems, the analyses of determinants of and returns to research investment based on such conceptual ambiguities may do more harm than good to already faltering agricultural research policy enunciation. More problematic is the uncritical acceptance of the truth of high returns to research effort, sanctified by the empirical evidence thus generated.

Section 2 presents a brief review revealing the conceptual confoundedness that marks the literature on economic analyses of agricultural research. We emphasize the need for conceptual clarity regarding the measure of research effort. In section 3 we present an expenditure measure of agricultural research effort for India. We contend that to use the measure to estimate returns to and determinants of research, (a) a perspective locating the research effort and its measure within an institutional context, (b) conceptualization of the distinction between the measure of research effort and the backward (determinants) or forward (agricultural productivity) linkage variables, and (c) at least a preliminary understanding of the research content thus measured, are most essential. In conclusion,

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in section 4, a few points that must be considered in any econometric estimation procedure using the measure of research effort, are highlighted. In economic analyses of agricultural research, the measure of research effort provides the starting point toward masking the historical and institutional context of agricultural science.

2. MYSTERIES AND MANIPULATIONS: THE CONCEPT OF RESEARCH EFFORT IN ECONOMETRIC ANALYSES

(a) *Determinants of research investment*

These studies estimate the determinants of resources (financial and personnel) devoted to research and allocation of these resources into commodities or regions. Guttman (1978) pioneered econometric analysis of determinants of investment in research. Guttman's study on "Interest groups and the demand for agricultural research," used a model of political interest groups and lobbies, to explain public allocations to agricultural research in the United States.[3] The supply of and demand for votes depended on the strength of the interest group and the political candidates favoring the policies sought by such groups. Interest groups demanding agricultural research products included consumers, farmers, and firms producing agricultural inputs.[4] Among them, farmers and input producers (especially of those inputs used intensively by new technology) were the two major interest groups working to direct public research resource allocation into their commodities or disciplines. In effect it proved that there were significant demand variables influencing agricultural research investment.

There are, however, both demand and supply variables that influence the level and allocation of research investment (Fox, 1987). In order to perfect the estimation of determinants of research, demand as well as supply variables were included in all analyses following Guttman (1978). Huffman and Miranowski (1981) showed a price inelastic demand for research and positive elasticity of supply of investment in US agricultural experiment stations. Higher agricultural output, greater diversity of crop production, higher share of large farms, increasing proportion of owner-operators, increase in input (labor) prices, and higher extension expenditures and research centers per farm, increased the demand for indigenous applied research.[5] Supply of research investment was positively influenced by relative richness of the state, higher share of research hours in total work-hours of scientists, and higher membership of farmers in cooperatives. Increasing diversity of agriculture (when leading to increasing regional specificity and higher share of applied research) was found to reduce the supply of research investment and "decrease the productivity of the station" (Huffman and Miranowski, 1981, pp. 115–116).

Supply of research is also determined by the location of research activity in the politico-bureaucratic hierarchy. In the United States, supply, i.e., state expenditure for agricultural research and extension is stimulated significantly by federal investment in research (Rose-Ackerman and Evenson, 1985). Using a political economy framework they stress the importance, in a democratic country, of federal direction and commitment to productivity-enhancing investments even when initial benefits are not evenly distributed. Their "regressions indicate that political structure affect state choices on agricultural research" (p. 8). They highlight the need for detailed "analysis of the politics of agricultural research and extension policy at the national level."

In an international analysis, country-wise and commodity-wise, Judd, Boyce and Evenson (1986), found that higher agricultural production and diversity of agricultural output increased national research investment. But high cost of research resources (ratio of cost of research personnel to extension workers) negatively influenced research investments in low income countries. Response of national research investment to export and import of agricultural products, terms of trade in agriculture, and free-riding on international agricultural research (transfer of technology), as well as allocation of investment among tradeable and non-tradeable products, was found to vary depending on national income levels.

Thus, several economic and political variables determine investment in research and its allocation. Research, in these econometric analyses, is an endogenous economic variable. These analyses assume that rent-seeking behavior by the ultimate beneficiary leads to public investment in agricultural research. Conceptually, the demand and supply variables specified in these models, conceal the causal relationships influencing decisions on investment in research. For instance, a high share of research in total work time of the scientists (in organizations where teaching, research and extension functions are integrated — as in the Land Grant Model of the United States) is included as a supply variable which induces a high level of spending on research. If a high level of research investment permits research stations to budget a high share of scientist time for research, the latter becomes a demand variable (see, Rose-Ackerman and Evenson, 1985, p. 2, note 3). In the historical context of the United States, articulation of client group demand for technology may induce public research investment. In a less-developed country, in the absence of such institutional mechanisms, government investment in research is determined by political vision to supply technological inputs for enhancing agricultural productivity. In other words the demand or supply effect of determinants of research investment is conditioned by the specific context. Depending on institutional arrangements which enable articulation of demand for investment or political vision to ensure supply of technology, the determinants and their causal relationships (in supply of or demand for research investment) vary.

These estimates of determinants of research investment violate all causal linkages in their use of the investment measure. Research, when measured as an input (research investment) will differ from research measured as output (additions to stock of knowledge or technology) (Kuznets, 1962; Schmookler, 1962). Investment when used as a proxy for research activity, assumes that the distinction between research activity and the investment, which is one of the determinants of activity, does not exist. In these studies, investment is also used as a proxy for research output. For instance, the price inelastic demand for research (output) and positive elasticity of supply of research (investment) are estimated using the same units of per capita state spending for research at a single time point. Moreover, conclusions about poor "productivity of research stations" (Huffman and Miranowski, 1981) are drawn from estimates of determinants of investment for the same time point!

The confusion in specifying the lag length ensues from this inability to differentiate research activity from investment and output and the use of research output in actual agricultural production. Estimation of determinants of investment in both research and extension, using cross-section data for one period or a given time point, collapses the complex (and iterative) process of invention, innovation, development and diffusion, to one event in one specific time point.[6] Conclusions drawn from such estimations are derived from coagulated conceptual grounds and must be treated with caution when propounded as research policy proposals. On the brighter side, similar econometric analyses estimating returns to investment, have become the key, more so in less-developed countries, to lobbying for increased public funding of agricultural research.

(b) *Returns to investment in research*

The level, growth and type of research investment are decided by the availability of resources, alternate uses, and government commitment to provide agricultural technology.[7] When public sector agricultural research uses national resources that have alternate uses, it is important to know the magnitude of economic returns resulting from these investments. This is estimated as "economic returns from investments" in agricultural research, and accounts for a major share in the literature on agricultural research. The significantly high rates of return to research investment compared to other public investments in agriculture or in other sectors, legitimizes further investment in research.

Estimation of returns to research investment is based on the fact that investment is an input into research activity, the output of which enters the agricultural production process as technology and improves agricultural productivity (Griliches, 1964; Peterson, 1967; Ayer and Schuh, 1972; Evenson, 1967). Returns to research have been estimated where research output enters agricultural production as a measurable quantity of technology, generally an embodied technology like new seed (Griliches, 1958), or as a measure of research publications (Evenson and Kislev, 1975). Since the economic validation of research output is subject to its end use in the agricultural production process, most studies estimate returns to investment (a readily quantifiable measure of research effort).

Schultz in 1953, pioneered the quantitative evaluation of agricultural research investments. He calculated the value of inputs saved through more efficient techniques of production relative to the expenditures on research and development. After Griliches's (1958) study on "costs and social returns for hybrid corn research in the USA," there were several works estimating marginal and average returns per dollar invested in agricultural research.[8] Annual internal rates of return ranging from 11 to 110% were reported for different national aggregate or individual crop/commodity research investments. (See Evenson, 1984 for a list of major studies.)

Estimates of agricultural research productivity in less-developed countries — mainly Brazil, Mexico, Colombia, the Philippines and India (Scobie and Posada, 1978; Ayer and Schuh, 1972; Evenson and Flores, 1978; Evenson, 1975; Evenson and Jha, 1973; Mohan, 1974; Bal and Kahlon, 1977), showed significantly high response of agricultural productivity to investments in research. These studies were on aggregate or crop-specific productivity in response to research investment; the major crops studied were sugarcane, cotton, rice, wheat and maize. In India, returns ranging from Rs. 6.6 to about Rs. 12 (in value of agricultural output) were estimated for every rupee invested in research.[9] A significant difference in returns before and after introduction of Green Revolution technology package was also noticed. While research investment in agriculture yielded Rs. 1.91 per rupee invested during 1960–61 to 1964–65, it increased to Rs. 14.91 in the post-Green Revolution period of 1967–68 to 1972–73 (Bal and Kahlon, 1977, p. 191). High rates of returns to investment were estimated for individual states (Punjab and Maharashtra) and crops (wheat and sugarcane) in India (Singh, 1977; Evenson, 1975; Patel and Waghmere, 1977).

Are these returns private or social? (Binswanger and Ryan, 1977). When the social cost of the value of labor lost (unemployment) is included in a (social instead of crop) production function, where a cost-effective, labor-saving technology enters the production process, the returns to research investment become the social returns. Thus, depending on assumptions about the opportunity costs of resources displaced, returns at the margin for every unit of investment in research on the tomato harvester range from 8 to 1288% (Schmitz and Seckler, 1970). The estimate of returns also varies depending on assumptions about the slope and shift of the agricultural supply schedule before and after introduction of the new technology (Norton and Davis, 1981).[10]

More recently, the debate on the impact of research on agricultural productivity has focused on the most appropriate approach and econometric technique to estimate returns. (See, Harvey, 1988; Thirtle, 1988; Thirtle and Bottomley, 1988; Beck, Upton and Wise, 1988.) It is doubtful whether "any meaningful relationship can be established from the available data" (Hallam, 1990, p. 434). But the "moral is that some sort of cost-and-returns calculations is possible and should be made" (Griliches, 1958, p. 385).

In all these studies, agricultural research (investment or output) is included as an input (in production function studies) in the production process, or as an imputed cost (in consumer surplus studies) in a supply schedule of agricultural output. Research investments, personnel, or publications are used as proxies for the research output that enters the agricultural production process as technology. In addition, the use of the production function in these analyses is questionable, since production functions assume a given state of knowledge. Research investment is an input in a production activity (research) which changes the production function itself, by changing the state of knowledge (Schmookler, 1962, p. 49). The output of research entered as input in a production function alters the state of knowledge. Unless the exact magnitude of the research output is known, it is impossible to specify the new agricultural production function. Output of research is not directly measurable; it enters the production process at various stages of the crop or enterprise (livestock/fisheries), in the form of embodied and disembodied technology.

Investment is, therefore, substituted for the measure of research output in these econometric models, regardless of the fact that research, when given as an input measure and as an output measure, gives two different quantities. Moreover, the time period between research investment and output (entering agricultural production) is rather long and varies from case to case. Even with a specification of lag length (generally given as 5–10 years), the continuous feedback of agricultural production information is a major determinant of (both investment in and actual conduct of) research.[11]

Returns to research effort, the methodological issues notwithstanding, are more than and distinct from returns to research investment, the latter being only one of the many variables that enable research effort. There are instances when a change in investment or allocation are not sufficient to direct research to produce the desired economic impacts. The prime example is the Indian Green Revolution. In 1966, the entire research organization was changed. A mere increase in investment would not have resulted in the success in Green Revolution technology. In the United States reorganization of agricultural research has been responsible for articulation of the goals of scientific research and delivery of research products (Lipman-Blumen, 1987).

Ultimately, in studies that estimate returns to public research, "there is a good case to be made for concentrating on the institution itself as an analytical variable" (Clark, 1980, p. 88). Decisions about levels and allocation of investment in a public research system are articulated first as research policy and then translated into manifest research projects. Several factors such as personnel strength and quality, availability of facilities or equipment, transfer of technology, work culture and so on decide the manner in which policy dimensions are translated to produce agricultural technology. While quantitatively abstracting research effort into an output or input measure, these complex institutional factors, the time period and the processes involved must be considered in as much detail as possible.

(c) *A measure and more: concepts and contexts*

When visualized as a process that transforms (financial and personnel) resources into (knowledge or technological) output, the analytical boundaries that demarcate a research process become significant in its measurement (Georgescu-Roegen, 1971, chapter 9). Thus, two measures of the research process are the input and output measure, obtained at the beginning or end of each year, measured in value of inputs used and value of output released. The input and output measures are unique and must be distinguished from the research effort that consumes resources and produces the knowledge or technological output. The end product of scientific research process can be knowledge and a product or a process. In either case they are inputs for further research processes. These output measures are often used as proxies for research investment in analyses of returns to investment in agricultural research. An output measure is obtained by (i) estimating the economic value or units of research output, (ii) imputing value of output based on number and standard of research publications, and (iii) enumerating and valuing other indicators such as patents for research products. The three measures of research effort at the output frontier are the output use, the bibliometric and the patent measures. At the input frontier, besides the measure of investment in research, the research personnel measure is also used. The indiscriminate use of these measures depending (rather blindly) on the availability of secondary data and the econometric convenience, has become standard practice in the works analyzing returns to and determinants of research.

We contend that a measure of research effort must be conceptualized clearly, historically and institutionally contextualized and explored for indicators of causal relationships, before it is used in an econometric model. For instance, conceptualizing the research process and the input and output measures is a prerequisite to distinguish a bibliometric measure from a research expenditure measure.[12] So is the case between an output use measure (as in the hybrid corn) and the research personnel measure. It is essential to contextualize the measure: say, by understanding the national publication policy, the "fixation power," the domestic and international publication patterns in the discipline, and the personnel policy for national scientists, if a bibliometric measure is used.[13] If an output use measure of embodied research products (seeds or chemicals or agro-machinery) is used, the measure has to be located within the context of the overall research agenda (of the research station concerned, the institute, and the region) and the respective outcomes of the research process, the extension operations and the farmers own experience.[14] Moreover, an output use measure must be contextualized in the dichotomy between the development and the adoption process which "separates the output of the R&D process from the outputs and effects exhibited in the production sector" (Capalbo, 1990, p. 110).

Likewise, an expenditure measure of public sector research effort, conceptualized as the value of public service provided by the government, can be studied and econometrically used, only in the context of the public sector in the country, the overall science and technology policy, and the institutional background of the research effort. With a sharper definition of what constitutes research activity, and an extension and refinement of our information regarding inputs in research, it may be possible to measure research effort with some degree of accuracy (Sanders, 1962, p. 75). To this end, it is essential that the expenditure measure be situated in the context of organization of the research activity it proposes to measure. We shall elaborate with a few examples, the centrality of "context" in this measure.

The first work using a measure of research effort was by Schultz (1953), measured as the "cost of R&D." Following this, research effort in producing a specific technology — hybrid corn, was quantified using research expenditure (Griliches, 1958). Evenson (1967), Evenson, Wagonner and Ruttan (1979), and Peterson (1967) measured research effort in the United States (in organizational terms — with research expenditure over time and across states), for individual crops and enterprises (poultry), respectively, to estimate returns to investment in research. An advantage of the expenditure measure is that it helps capture the organizational or functional break up of research effort.[15] To understand research effort in a public research system, details of expenditure across institutes, projects, disciplines and personnel must be examined.[16]

But an expenditure measure in itself may overestimate the level of research effort if the resources are underutilized in the organization. A research organization may "adapt or develop" a research product produced by inventive activity outside the existing national system. Major breakthroughs in agricultural science have resulted from research projects with limited resources, or as by-products from projects meant for other purposes.[17] Often, research activity is not entirely accounted for by the expenditure incurred by the organized science sector. An analogy to the Philippine farmer's discovery of the Dee-Geo-Woo-Gen cultivar of rice which revolutionized rice production in Asia, is Schmookler's observation that "half of the patented innovations were made by individuals who lack college education" (Schmookler, 1957). All initial research for the Indian Green Revolution technology was done by scientists in the Rockefeller Foundation and US Department of Agriculture (USDA) using funds from their respective sources and the Mexican government. It is a fact that research expenditure in India accounts only for a part of the research effort that produced Green Revolution technology for Indian agriculture. We could safely argue that estimates of returns to investment in Indian agricultural research are based on a measure that accounts for approximately one-quarter of the total research effort that precipitated the Green Revolution in the country.

The unprecedented globalization of science has effected changes within a country, that make "national" expenditure measures inadequate if not entirely redundant.[18] Moreover, in international comparisons, country-wise variations in price of research services may bring misleading comparisons (Evenson and Kislev, 1975a).[19] The price of research service does not vary among regions within a country; especially so in India, with a national grid that controls all the research functions. In the following section we present the National Agricultural Research Expenditure (NARE) measure for India.[20] The conceptual, contextual and causal significance of the measure is examined.

3. EXPLORING THE NATIONAL AGRICULTURAL RESEARCH EXPENDITURE SERIES

(a) *Institutional context of the NARE*

The national agricultural research expenditure is defined here as the total expenditure incurred for agricultural research activities undertaken by the public sector in the country. Based on the Pardey and Roseboom (1989) classification, we present the components of this research expenditure measure as follows:

(i) *National*

The "national" classification includes all research activity within the country, which includes all centrally funded research, and all state-funded research in the public agricultural research system in India. The International Agricultural Research Centres, located in the country are not included.[21]

(ii) *Agriculture*

The "agricultural" classification includes research on some basic biological and physical sciences, and research for all crops, resources, animal husbandry, dairying and fisheries enterprises conducted by the public research system.[22]

Those public organizations within the formal agricultural research system in which research is the major or only function, are included. Public agencies that undertake research, in the agricultural sciences directly or in any other related field, as one part of its routine function and not as its major function are excluded.[23] Thus the public sector firms or industries involved in fertilizer research, plant-protection chemical or varietal trials, engineering experiments (efficient plough-shares for tillers) for crop production, or post-harvest/storage research, as part of their major function of manufacture of fertilizers and chemicals, seeds or agromachinery, are included only so far as the share of their research funding coming from the central or respective state governments is concerned. In India, however, they are not a significant part of the agricultural research effort in terms of size of effort/expenditure.[24] The list of all research stations/institutes that have been included as "agricultural" research stations are:

— All research stations/institutes under the Indian Council of Agricultural Research (ICAR)

— All research stations/commodity committee research institutes that existed under the Central Ministry of Agriculture, but outside the ICAR (before 1966)

— All research stations/institutes (or research funded by the) under the Central Ministry of Agriculture and the Ministry of Commerce (speciality crops such as tea, coffee, rubber)

— All research stations/research work undertaken in colleges, under the State Agricultural Universities (SAUs)

— All research stations/institutes/research funded by the State Departments of Agriculture, Animal Husbandry and Dairying, Fisheries, Soil and Water Conservation, and Forestry, outside the SAUs.

(iii) *Research*

The "research" classification includes only the research function. Research expenditure includes personnel costs, material costs, managerial or administrative costs, and imputed value of capital/equipment and other infrastructure used for research purposes. These are broadly, the quantitative inputs that go into research.

A comprehensive picture of the components and the resource flows that constitute the national agricultural research expenditure, will enable identification of the basic structural and functional relationships in the research system. The major sources of research funds are the central and state governments (see Figure 1). The research foundations include domestic semi-autonomous foundations such as voluntary agencies, or other international agencies (World Bank), or bilateral arrangements (the US Agency for International Development or PL 480 assistance) for research.

The ICAR is the nodal point for all resource flows in agricultural research in the country. Central gov-

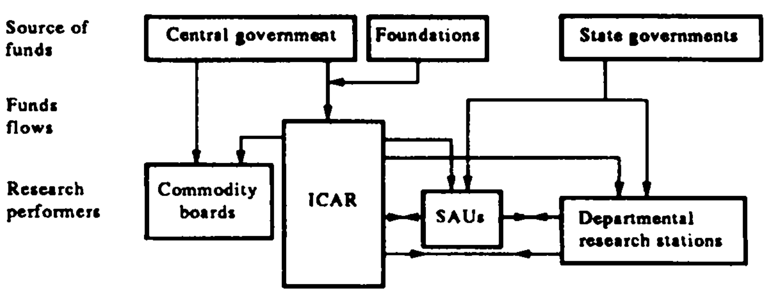

Figure 1. *Flow of agricultural research funds in India.*

ernment grants are the major source of funds for the ICAR. All other receipts, the Agricultural Produce Cess, receipts from other Departments and Research Foundations, are directed to the national research system through the ICAR. Individual state governments fund respective SAUs and state departmental research stations. The ICAR also contributes funds and research guidelines to these state agencies. Besides these vertical flow of funds, schemes such as the All India Coordinated Research Projects are shared by the ICAR and SAUs or ICAR and Departmental Research Stations. In Table 1, the sum of the central and state expenditure equals the NARE for India.[25] Major changes in 1966 and 1974 in the organization of the ICAR, and since 1960s in the states (establishing SAUs), affected public funding of research and the rate and direction of inventive activity in these organizations.

An examination of some estimates of NARE made previously reveals that several assumptions are made to arrive at the estimates (Mohan, Jha and Evenson, 1973; Evenson and Jha, 1973; Mohan, 1974; Pardey and Roseboom, 1989). These assumptions and judgments, often violating the spatial and organizational reality of agricultural research, account for the difference between our estimates presented in Table 1 and these other measures.

(b) *Examining the NARE series*

Assumptions and judgments about the basic data used are potent enough to mislead the entire analysis. The most cited study on Indian agricultural research, reports that "an investment of one rupee in agricultural research gave a return of 11.61 rupees," during 1961–73 (Kahlon *et al.*, 1977, p. 131). The study, as the authors inform us, is marked by "weakness of the data." We find that the data reveal growth rates that contradict the actual context of agricultural research investment during the period. For instance, the compound growth rates reported for expenditure in agricultural research at the all-India level, are 7.58% and 6.08% respectively for 1960–61 to 1964–65 and 1967–68 to 1972–73 (p. 127). This is taken as evidence that "the rate of growth in agricultural research was steady over the two periods" (p. 128). Besides it also helps validate the five-year time lag between research investment and returns used in the study (Appendix 5.2, p. 144). In other words, the increased

Table 1. *National agricultural research expenditure (Rs. Lakhs)*

Year	Central Govt Research Expenditure	States + UTs Research Expenditure	Total National Agricultural Research Expenditure	NARE (constant price 1970 = 100)	Index of Research Expenditure
1961	244.62	360.40	605.06	1052.80	100.00
1962	251.71	404.30	656.04	1097.61	104.26
1963	296.07	446.40	742.49	1196.24	113.62
1964	250.58	563.70	814.28	1253.85	119.10
1965	282.73	687.20	969.94	1361.05	129.28
1966	317.46	828.20	1145.63	1510.15	143.44
1967	819.96	893.40	1713.31	2041.89	193.95
1968	1088.53	1029.10	2117.62	2317.39	220.12
1969	1365.47	1090.60	2456.06	2654.38	252.13
1970	1526.53	1256.50	2783.00	2899.65	275.42
1971	2010.62	1412.00	3422.63	3422.63	325.10
1972	2591.50	1660.70	4252.20	4110.46	390.43
1973	2854.57	1937.40	4791.99	4342.74	412.49
1974	3119.61	2087.00	5206.57	4099.29	389.37
1975	3101.97	2105.70	5207.68	3356.06	318.77
1976	4216.14	2572.90	6789.08	4264.62	405.07
1977	5035.28	2661.50	7696.76	4834.79	459.23
1978	6164.13	3081.50	9245.63	5434.93	516.24
1979	7227.50	3230.90	10458.39	5946.93	564.87
1980	7616.30	3725.70	11342.01	5980.33	568.04
1981	8243.78	4116.90	12360.68	5828.62	553.63
1982	9774.49	4756.40	14530.93	6121.99	581.50
1983	11319.01	4851.00	16169.96	6308.46	599.21
1984	12479.42	6050.70	18530.15	6553.35	622.47
1985	14673.75	7173.20	21846.92	7145.42	678.71
1986	15682.09	8126.30	23808.43	7293.43	692.77
1987	17386.55	9206.20	26592.71	7548.34	716.98

Sources: ICAR, *Annual Reports* (various years).
CAG, *Combined Finance and Revenue Accounts of the Central and State Governments in India* (various years).

research investment in the first period is revealed as productivity growth, with a five-year lag, in the second period.[26] We contend that such findings based on weak data and flimsy conjectures, not only distort the history of Green Revolution technology in India, but also lead to underinformed policy decisions.

When located in its institutional and organizational context, the expenditure measure of research effort can indicate the possible relationship between research activity and agricultural output. These primary exploratory insights constitute the essential basic information regarding the context and the causal relationships, in the event of further econometric analysis.

Table 2. *Share of central and state governments in national agricultural research expenditure*

Year*	Share of Central Government (%)	All State Governments (%)	Total NARE (Rs. Lakhs)
1960–61	40.43	59.57	605.06
1965–66	27.71	72.29	1145.63
1966–67	47.86	52.14	1713.31
1973–74	59.92	40.08	5206.57
1974–75	59.97	40.43	5207.68
1980–81	66.69	33.31	12360.68
1986–87	65.38	34.62	26592.71

*Selected years indicating organizational changes.
Source: Table 1.

(i) *Rate of change*

Public research effort as indicated by the expenditure measure, shows a significant difference in growth pattern between central and state research (see Figure 2). The Constitution of India assigns responsibility for agricultural research to the state governments, with central responsibility being limited to coordination and determination of standards in institutions for higher education or research and scientific and technical institutions.

The expenditure shares shown in Table 2, however, reveal that about two-thirds of NARE come from the central government, handled exclusively by the ICAR, and that this significant share was consolidated over a period of two decades (1966–67 to 1987–87).

That this apparent centralization has occurred in three distinct periods, corresponding to points of organizational change, is evident from Figure 2. These changes are substantiated by the period-wise compound growth rates (Table 3), each period corresponding to distinct phases in agricultural research in the country. Overall growth rates of central and state research expenditure (10.84 and 4.79% respectively) demonstrate the increasing centralization of research compared to regional/state research capacity. During the first period, starting 1961, until the reorganization of the ICAR in 1966, the negative growth rate of central research expenditure is in contrast to the growth rate of 11.49% in the states. This difference corresponds to the difference between the uncoordinated multiple agency central research effort and the relatively decentralized, research "capacity building" (with international technical assistance) in the states during the period.[27]

The rapid growth period following reorganization of the ICAR in 1966 is marked by increasing centralization. This second period witnessed expansion of the Council from coordination to direct handling and central control of research. Following the second reorganization of the Council in 1974 (the third period) growth of Central and State research expenditure has slowed down considerably. These basic descriptive statistics of the expenditure measure of research have revealed that changes in the organization of research activity are central to understanding or explaining the measure of research effort. This institutional context is integral to explaining the relationship between research effort and agricultural production.

(ii) *Research effort and agricultural output: making a case for conceptual clarity*

We use the detrended NARE series to examine how the changes in research effort are reflected in the significant changes in Indian agricultural production.[28] No empirical estimation of impact of research is attempted. The purpose is to examine whether the NARE series as a measure of research effort can reveal changes in the content of research over time, which in turn will be evident in the agricultural production pattern.

The content of research effort, may be self-evident in a fairly disaggregated functional breakdown of research expenditure. In relatively direct terms, a crop-wise breakdown of research expenditure can provide a first-hand tangible account of research content. But research content is distinct from the measure. It reveals or at least permits a cursory view of the research process contained within the input and output frontiers. In other words, research content, in terms of strategic orientation of a discipline(s), tactical subphases of intradisciplinary evolution, interdisciplinary convergence or tangents, and the implicit time-value paradigm, reveals the exact manner in which research policy decisions are translated into research projects and transformed into research products (knowledge and/or technology). For instance, crop-wise distribution of research expenditure in the early years of the ICAR as compared to allocation pattern in more recent times reveals the distinct shift in concentration from commercial crops to food crops.[29] In a very broad policy perspective this validates the social context of scientific research: from colonial commercial interests to national quest for food self-sufficiency. Intra- and interdisciplinary orientations on the other hand help explore the very process of scientific research, always the reverently untouched black box.

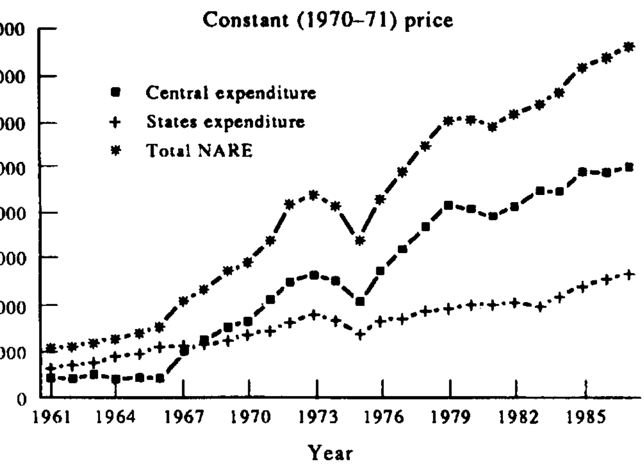

Figure 2. *National agricultural research expenditure, constant (1970–71) price.*

Table 3. *Annual compound growth rates of research expenditure* (percentage (%))*

Phases	Period	National	All States	Central
Overall	1960–61 to 1986–87	7.94	4.79	10.84
Phase I	1960–61 to 1965–66	7.13	11.49	-1.36
Phase II	1966–67 to 1973–74	11.31	7.45	14.47
Phase III	1974–75 to 1986–87	5.35	4.40	5.88

*In constant (1970–71 = 100) price
Source: Table 1.

The Green Revolution of the 1960s, brought a convergence of disciplines, in terms of their approach to the problem of increasing crop production. Plant breeding and genetics had shifted from improvement and selection-breeding and segregation studies, to selective hybridization and genetic transformation/manipulation studies. All other disciplines, pathology, entomology, agronomy, soil sciences, and agricultural engineering, had also shifted from a defensive research strategy that was applied till then, to a completely offensive research strategy. This shift in research content was explicated in Dr. M. S. Swaminathan's request for reorganization of research, so that it could be reoriented with a dynamic wheat-breeding program and intensification of research in disease resistance. This would translate the national goal of food self-sufficiency into an applied research strategy. The ICAR was thus reorganized in 1966, following the Parker Committee recommendations, with two main objectives:

> creation of an incentive system that would encourage more research from professional personnel, and establishment of an organizational framework that would enable them to focus on the most urgent problems (Ministry of Agriculture, 1964; Lele and Goldsmith, 1989).

Research expenditure was increased along with the reorganization, and the Council came to be headed by a scientist in place of a bureaucrat. As recommended by Dr. M. S. Swaminathan, India had to shift to a dwarf wheat-breeding program in order to get full benefit from the fertilizer and water components of the package program introduced under the IADP (Randhawa, 1986, p. 368; Sivaraman, 1991, chapter 10). The urgency was evident in the swift changes in research content during the period.

A quick short-term convergence of research disciplines, revitalized input supply strategy, favorable price policy, and ample international technical assistance, led to the successful production results of the Green Revolution. It is now common knowledge that Green Revolution productivity trends started showing increases from 1967–68 harvests. We contend that it was this short-term mission-oriented research content that made this miracle in Indian food production possible. With a project-wise disaggregation of the expenditure measure, such intra- and inter-disciplinary movements would be evident.[30] In the following graphical representations of the research expenditure series we examine how the research expenditure itself is an indicator of changes in content and organization, and of the changing relationship between research effort and agricultural productivity.

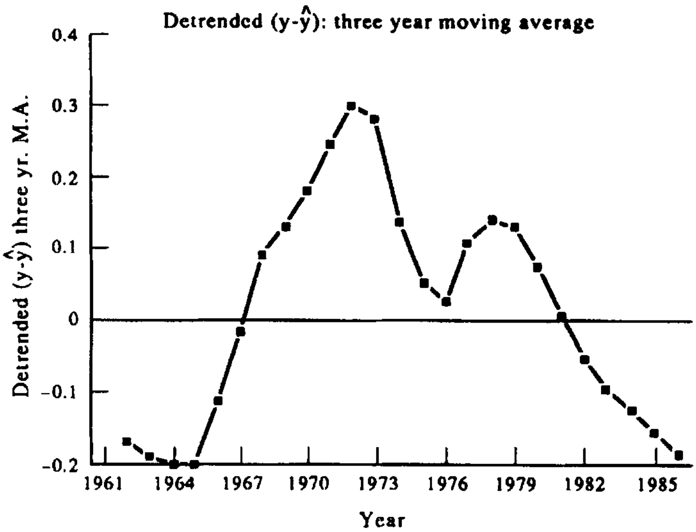

Figure 3. *National agricultural research expenditure, detrended (y – ŷ): three-year moving average.*

The detrended NARE series reveals the real growth cycle of research effort (see Figure 3). Real research expenditure had reached a peak in 1971–72. The steady phase of decline that followed gathered momentum after 1979–80. A small and short upswing within this declining phase is noticed between 1975–76 and 1980–81. The increase in pay scales of ICAR employees in the wake of the Agricultural Research Service and the reorganization in 1974 is responsible for this short cycle. Stagnation in research expenditure during the 1980s, observed in growth rates (Table 3) is evident in the cycle of research expenditure.

When the cycles of growth of the NARE and the agricultural Net Domestic Product (NDP) are compared, the extent of association between the two in the late 1960s is evident (see Figure 4). Agricultural NDP does not show a slump in the 1980s, as the NARE does. The dichotomy between the output of research and the manifestations in the actual agricultural production sector (between the R&D and the adoption processes) is evident here. An excessive concentration on wheat in the total agricultural research effort (especially in the 1960s and early 1970s), and an increasing share of other crops and livestock and other sectors in agricultural NDP since the late 1970s, may also account for this dissociation between the two series in the 1980s. The agricultural NDP (output net of input) figure may also account for this dissociation, if increases in input use alone, without adoption of the entire technology package (designed within the semi-dwarf plant-type paradigm), results in output growth. In other words, it may be due to concentration of research effort on wheat and the increasingly input-

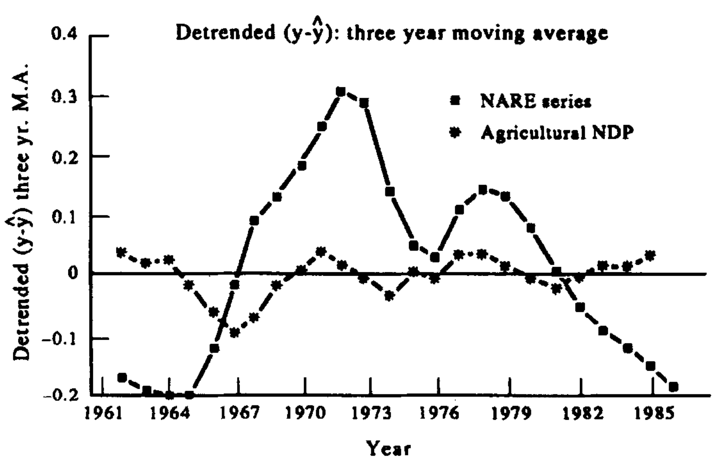

Figure 4. *NARE and agricultural output, detrended (y – ŷ): three-year moving average.*

augmenting nature of research activity, directly the result of the convergence of research content along the new offensive research strategy. If allocations to wheat research have been significantly high since the mid-1960s (Green Revolution), there must be a correspondingly high association between the NARE and wheat output. The detrended series of wheat production and NARE reveals a high association (see Figure 5). Wheat production which had touched the trough of the cycle in 1965–66, starts picking up momentum barely one year after research expenditure enters the period of rapid growth. This evidence from the NARE series, reiterates the discussion above on change in research content and research organization.

In research content, considerable research on manurial trials (even leading to accusations of repetitive and ritualistic research) is handled by the public research organization (ICAR, 1988, pp. 70–71). In a detrended plot, we observe a high level of association between fertilizer consumption (in thousand tons of nutrients, NPK) and the NARE (see Figure 5). The short lag lengths observed in Figure 5, both for wheat production and fertilizer use *vis-à-vis* research expenditure are significantly related to the high share of applied and adaptive research in the total research effort. Indian research effort was involved only in the tail-end "development" of technology generated in an international research program.[31] That the research system did a commendable and remarkably swift job of converting international applied research results into technology for local use (especially varieties and manurial recommendations), is certainly indisputable.[32]

The expenditure series thus discloses several organizational features that can help explain research effort during each period or phase. Implications of this association for agricultural research in India start from the historical evolution of research effort, and extend to the future effectiveness of public sector agricultural science and research. Even the high association observed in the case of wheat output and fertilizer use seems to have little to do with impact of research activity within India. If research effort in recent times, in the 1980s, does not show the high association of past years, it may have serious implications for future effectiveness of maintaining a heavy applied research strategy, the effectiveness of international transfer of technology and the general stagnation in research output during this transition phase in global agricultural research from Green to "gene" revolution. This, however, is beyond our agenda here which is limited to understanding how in its basic conceptual clarity, the measure of research effort precludes interpretative violation of the spatial, temporal and social facts of actual research effort.

4. THE MEASURE: SIGNIFICANCE AND USE

Before our concluding remarks on the use of an agricultural research measure, we draw attention to two (thematically contradicting) works. The first, the report of the Airlie Conference, where one of the themes was the technical issues related to the measurement of research productivity, dramatically influenced agricultural research policy and investment decisions, and the establishment of new/strengthening of old agricultural research organizations in almost every developing country (Arndt, Dalrymple and Ruttan, 1977). Amid much skepticism about the Green Revolution technology,[33] it was the leader urging decision makers in poor countries to take up the

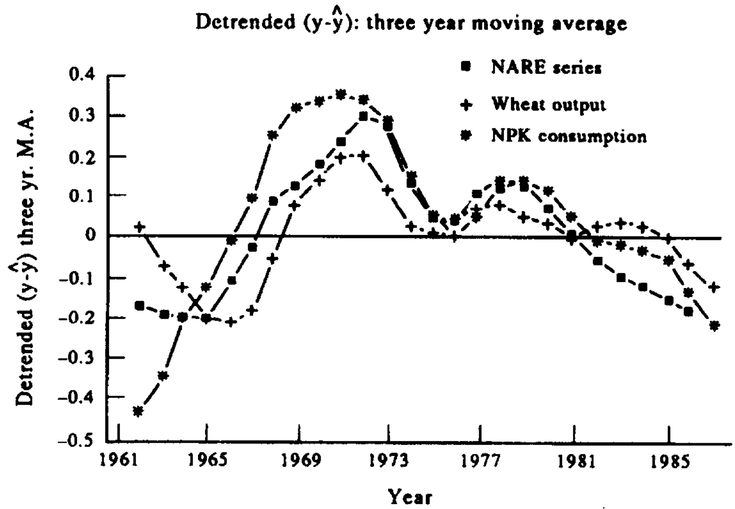

Figure 5. *NARE, wheat output and fertilizer use, detrended (y − ŷ): three-year moving average.*

cause of agricultural research. In effect, it propagated the "truth" of technology, second to no other tool of development. The second work we wish to recall here, dates much earlier and conveys the need to question this truth. In his seminal work on the political economy of institutions, Commons held that scientific truth is tentative, relative to the interest it serves. The single truth of consistently high returns to research investment, so repeatedly confirmed (irrespective of the crop, region, or cultural or political context), would therefore, be both "distasteful and untrue" (Commons, 1934, p. 831, as quoted in Copeland, 1936). Commons calls for truths that are proportionate to each other, in order to get the optimum truth that will work in a world of conflict. This allows us to focus on the given logic of abstractions and assumptions in economics which repeatedly qualifies the single truth of consistently high returns to research.

The significance of the research measure is manifest in its capacity to present alternative truths about the returns to research effort. The very measure of research effort based on which the returns are estimated, is sensitive to different institutional contexts and historical processes that have influenced both agricultural science and agricultural practice in the region/crop concerned. But in concentrating on the methodology for estimating returns, economics seems to have lost the iron and perfected the anvil. The central variable, research effort, is always taken for granted. That it may in itself dictate the methodology or functional form for analysis is never given due concern. In short, the methodological debates are sadly lacking in their conceptualization of the research process, its measure and content, and its causal relationships, especially with agricultural productivity.

For instance, a state-wise analysis of returns to research investment concludes that the research expenditure variable did not positively influence agricultural output in Andhra Pradesh, while it did in Bihar, Punjab, and Maharashtra[34]. It is well known that this has to do with the research content (which had little to offer traditional rice-growing areas) in the 1960s, and more poignantly, the research expenditure measure, which for states such as Punjab and Bihar were complemented heavily by central research investments. Moreover, in terms of causality, the lag lengths between investment and research effort, and between research effort and research output, depend not only on the research content and the institutional context, but also on the effect of complementary inputs in the research process (education or research capacity building). Clearly, states such as Punjab, Maharashtra and Bihar had the advantage of an early start in these complementing factors (Randhawa, 1986).

Given the center-state funding arrangements and institutions for agricultural research, a production function estimating the returns to investment in India, demands two lag specifications for ICAR and SAU investments, specifying at each instance a dummy variable for inter- and intrainstitutional transaction costs.[35] Again, the returns estimate for the ICAR is incomplete without including the continuous feedback in terms of personnel and research problems, that it gets from its research capacity building activity. The functional classification of work (teaching, research, and extension education) in the SAUs will, on the other hand demand that the research expenditure measure appear with a discount rate to account for personnel time incurred or facilities accounted (labs or experimental plots), on activities other than research. Locational specificities that confer different functional allocation patterns for the SAUs demand that a (convenient) uniform weight or discount rate cannot be applied blindly for all SAUs. (See Appendix A here for a brief note.)

A sufficiently disaggregated research expenditure measure giving a breakdown of allocation to basic, applied and adaptive research, is crucial for specifying lag length. India, with a relatively low basic research component, concentrating on applied and adaptive research, will have a short lag length between research investment and research output, and between research output and its impact on agricultural production. The heavy basic science component in many developed countries does not, however, imply that a relatively long lag length exists. On the other hand it may imply that the causal relationship between (mutual determination of) research effort and agricultural productivity may continue for over 30 years, and not stop at 6.5 or seven years (Pardey and Craig, 1989). A high share of basic research creates an exponential impact on applied research, by generating scope for more mission-oriented technologies. In a production function, therefore, the measure of research effort must be entered in two components, one with a relatively long lag length and the other with a simultaneous and progressively shorter lag length in the applied research share. The measure of research effort may also demand a different functional form depending on the cumulative, step-wise additive, or exponential reactions that the research output has on the objective variable (say overall productivity, soil quality, or pesticide efficacy). Disaggregation in terms of interdisciplinary spill-overs is also essential in the case of such specific objectives.

That we have not attempted to specify any functions or estimation models may be considered a weakness. Let us recall that doing so would be the very antithesis of our objective. We maintain that each context — geographical, institutional and organizational, epochial, disciplinary, crop/resource, entrepreneurial, social and cultural — will have a particular impact on both the measure (or appropriate combination of measures) of research effort and the model for estimating returns to research effort. In fact when the question is one of estimating welfare from changes in quantity of research (a public good) as against the standard benefits and costs of research, the economist even has the choice of using a Hicksian welfare measure or the usual Marshallian surplus measure (Alston and Larson, 1993). While it is important to know the impact of research, the exercise of estimating returns must also include the realities of a society of conflicting interests, be it the tomato harvester versus labor, or scientists versus administrators, or ecologists versus pesticide firms, or enclaves of scientific specializations. Returns to research effort are not limited to an estimation of benefits.

Obviously, the measure of research effort has played a significant role in abetting the unsullied image of scientific research and the technology it generates. From the measure of research effort used, to the blatant assumptions about lag lengths, economics has helped create this myth of consistently high rates of return to agricultural research investments. Conceptual clarity regarding the measure is essential to understand the research process, the social, economic and organizational constraints and conflicts that engender research. Econometric specifications without such an institutional basis and conceptual clarity are of little use for effective policy making. Ultimately, it is important to recognize that the measure of research effort and its use in an econometric model to estimate returns to or determinants of research, cannot be isolated from the historical institutional evolution of agricultural science and agricultural practice in a society.

NOTES

1. See Evenson (1984), and Norton and Davis (1979), for a review.

2. Guttman (1978); Huffman and Miranowski (1981); Judd, Boyce and Evenson (1986).

3. Interest groups are groups of individuals or firms which jointly "purchase" policies (collective goods) favorable to themselves. The medium of exchange in those transactions may be votes or campaign contributions to politicians (Guttman, 1978, p. 468).

4. Variables such as education of the farmers, amount of or level of borrowed research, sales per farm, ownership or tenure condition of the farm, farmer groups in other commodities, input-producing firms, membership in cooperatives, state budget size and dummies for the commodity class (such as poultry or grains or dairy products) are used to explain demand for research. State allocations to research in the specified commodity class, relative to state population is the dependent variable (Guttman, 1978).

5. The demand for research investment, when considerable borrowable applied research output existed in other similar states, was significantly low when proportion of large farms was high, and relatively high with more medium farms (Huffman and Miranowski, 1981).

6. See Bonnen (1987) and Stoneman (1987) for a discussion on the distinction between the creation, development and utilization of knowledge.

7. While level and growth indicate the quantity of resources expended on research, type of research investment indicates the orientation or purpose. It may be investment to solve an immediate production problem, or long-term investment to ensure a continuous flow of agricultural technology. Thus, investment may be for applied or basic research. See Arnon (1975); National Commission on Agriculture (1976); and Bonnen (1987).

8. Estimates of average rates of return are obtained from a consumer surplus approach — where research investment enters as an imputed cost in the agricultural supply function, and the marginal rates of return from a production function analysis — where research investment is the residual or one of the variables in an agricultural production function. See Evenon (1984); and Norton and Davis (1981).

9. Mohan (1974) estimated Rs. 6600 for every Rs. 1000 invested. Evenson and Jha (1973) estimated an internal rate of return of 50% and an average return of 10.88 rupees per rupee invested in research during 1953–54 to 1970–71. Kahlon *et al.* (1977) estimate 63.3% and Rs. 11.61 respectively, from 1960–61 to 1972–73.

10. In a consumer surplus approach to estimate returns, the nature of supply shift assumed, influences the estimate of distribution of benefits of research between consumers and producers. Divergent shift in supply schedule results in fewer benefits to producers, than either convergent or parallel shifts (Norton and Davis, 1981, p. 689).

11. Estimation of mutual and simultaneous causality between research investment and agricultural production in the United States, showed that lag lengths of at least 30 years may be necessary to capture all the impact of research on output (Pardey and Craig, 1989, p. 18).

12. The various input and output measures, their conceptual basis and use are discussed in Rajeswari (1992), chapter 3.

13. Fixation power in publication is the ratio of studies published in a country that are carried out by the scientists of this country using resources within its own national research system. India is more internationally oriented than many other developing countries, with a fixation power of only 34.9%. Moreover, being a country in the South may itself imply a different publication pattern, indicating a different research content, with certain topics receiving a lot more attention than the conventional Northern topics. See Arvantis

and Chatelin (1988).

14. A HYV (research output) can be measured by its acreage. But how much of this acreage is the result of research and how much of it is in response to other incentives, problems or farmers traditional wisdom, is beyond quantification. See Biggs (1978 and 1990) and Biggs and Clay (1983) for various sources of innovation and informal research and development (R&D) in agriculture.

15. Classifying research on the basis of the nature of the R&D activity itself, rather than its principal economic objective, is called a "functional" approach (OECD, 1981, p. 53, quoted in Pardey and Roseboom, 1989, p. 12). A break-up of research expenditure by type (basic/applied/adaptive), or topic (agronomy/soil-science/phyto-pathology) is a functional classification.

16. It is not enough to have a national aggregate figure of R&D intensity. The nature of this distribution is important if the innovation system in a country or industry is to be understood (Hughes, 1988).

17. The "basic idea of hybrid corn was developed between 1905 and 1920, with the help of very little money" (Griliches, 1958, p. 379). See also Paarlberg (1988), and Pearse (1980); for details of how the research project to produce disease resistant wheat and corn for Mexico led to the breakthrough in semi-dwarf wheat varieties that revolutionized agriculture in the 1960s. Delving further, what proportion of the Mexican (Rockefeller, USDA, Mexican Government) research effort is accounted for by the US military (which occupied Japan in the post-World War II period and brought Norin 10 to Washington) and the Japanese national research effort?

18. See Dore (1989) for the irrelevance of the economic and technological identity of a nation state in the present world.

19. Cost conversions to constant (1980 US dollars) have taken care of some of the problems in comparison (Pardey and Roseboom, 1989). But differences in value levels (say, the number of scientists employed per $100 in the United States and India) persist. This makes international com parisons of research effort difficult.

20. See Rajeswari (1992), Appendix 3.1 for details of computation of the NARE series.

21. All research funded by international agencies (such as the World Bank) and undertaken through the public research system are included in the research expenditure series.

22. There are several variants of agricultural research expenditure defined and used in production function analysis. Evenson (1967) used total research and extension expenditure by the State Experiment Stations and USDA, while Bredahl and Peterson (1976) used commodity specific research expenditure by the state experiment stations alone. In their review, Norton and Davis (1981) report that some studies have used research and extension expenditures by state stations, the USDA, and the soil conservation service.

23. See classification of R&D establishments by Department of Science and Technology, Government of India, in *R&D Statistics*, DST (annual). Our classification of national research effort would roughly correspond to the Major Scientific Agencies (MSA) of the DST classification.

24. See Table A3. Part of these figures are incurred from Central or State Government budgets and, therefore may enter our data. While in 1976–77 the public industry expenditure for agricultural research was 4.47% of the total national (Central and State Governments and private sector) expenditure for the same, in 1986–87 it was 3.15%. The same share in total public sector industrial research expenditure was 4.48% and 3.25% respectively in 1976–77 and 1986–87. One reason for this steady decline in share of public agro-industries in total agricultural research is perhaps due to the increasing presence of the private sector in recent years (Pray, 1987).

25. Details of the computation are available with the author and the editor of *World Development* and can be forwarded on request from interested readers.

26. Sadly, the lag length used comes from an estimate made for the United States by Evenson, which "is between six and seven and a half years. For our study we have considered the time lag to be five years, which became obvious from the jump in research expenditure during 1961–62 and the jump in agricultural production in 1966–67" (Kahlon *et al.*, 1977, p. 144).

27. See Naik and Sankaram (1972), and Rajeswari (1992), chapter 7.

28. For a detailed discussion on detrending time series data and the cyclicality of growth, see Anandraj (1992).

29. Between 1929–30 and 1939–40 the ICAR expenditure for sugarcane research alone accounted for 18% of the total expenditure by the ICAR, while rice, wheat and other cereals accounted for only 13%, within the 39% share of total expenditure accounted for by agricultural schemes (Rajeswari, 1992, pp. 139–140). During 1980–81 to 1989–90, the ICAR allocated over 58% for food crop research, within the 74% allocated to crop research from its total government grant received (ICAR, *Annual Report*, relevant years).

30. See ICAR *Annual Reports* 1964–1969, especially see Audited Accounts in these reports.

31. Wheat was the lead Green Revolution crop. India derived a major share of its growth in agricultural output from growth in output of wheat (Sen, 1979). All basic research and even most of the applied research for this crop was done by agricultural research systems outside India. Therefore, when the reorganized ICAR in 1965–66 took to heavy applied research in wheat and the Green Revolution package, the time period required for their technology to effect changes in output was very short.

An effective example is the case of Sharbati Sonora, India's most popular dwarf wheat variety. Four varieties from Mexico, *viz.*, Sonora-63, Sonora-64, Lerma Rojo-64A and Mayo-64 were introduced in India in 1963–64.

Following discovery that Lerma Rojo and Sonora-64 were best suited to Indian conditions, the IARI, in 1965 "employed a mutation breeding programme in order to improve the grain characteristics of Sonora 64" (ICAR, 1973, p. 145). This project was started about the same time in 1965 that Lerma Rojo and Sonora-64 were approved by the Central Variety Release Committee of the Government of India in 1965. This gives a gap of approximately 1.5–2 years between the first research in India on these varieties and their release for cultivation.

Results from the trials on Sonora-64 at the IARI, by Dr. M. S. Swaminathan, were available by 1967. Sharbati Sonora which was selected as the best of these Sonora progeny was *"included in the All India co-ordinated Wheat Trials in 1967–68 and released for cultivation in 1967"* (ICAR, 1973, p. 145, emphasis ours). From the other accessions sent by CIMMYT in 1963–64, five were selected and released for cultivation during the same period. See Gill (1983, p. 97) as quoted from Athwal and Borlaug (1967), and Kohli and Anderson (1967). There is reason to believe that Indian agricultural research (which was involved only in the tail-end of the research process for a few wheat varieties) was reflected in the growth of agricultural output with a lag period of about 2–4 years.

32. Evenson and Kislev (1975) highlight the need for a sufficiently advanced domestic research system, for successful international transfer of technology.

33. See Pearse (1980) and UNRISD (1974). See also Glaeser (1987).

34. Kahlon *et al.* (1977, p. 139) also assume a uniform lag of five years for all states, thus negating the very diversity of agricultural production and research effort among the states.

35. The transaction cost within institutions may involve incentives and disincentives, administrative bottlenecks, hierarchies, interdisciplinary frictions, and the like. Between institutions, however, the problems are compounded by various contractual arrangements. Thus, if the very organization of the AICRPs provides a "built-in mechanism of not completing the projects" since the scientists have to return to their previous assignments if the project is completed, it must enter as a heavy transaction cost/lag variable in the model. See, Chowdhury, Gaikwad and Bhattacharya (1972).

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APPENDIX A

PREVIOUS MEASURES OF NARE: A COMPARISON

The Mohan, Jha and Evenson (1973) study constructs time series of research expenditure during 1950–68, after certain adjustments, "many of them judgmental" (Mohan, Jha and Evenson, 1973, p. A–22). We shall examine the assumptions made in this study in some detail because estimates of Indian agricultural research expenditures given by Mohan, 1974; Boyce and Evenson, 1975; and in the ISNAR Global Research Indicator Series by Pardey and Roseboom, 1989 are based on estimates in Mohan, Jha and Evenson, 1973.

Regarding the Central Research Expenditures, these judgments relate mostly to computation of the actual research expenditure by the ICAR. The estimates reveal an inadequate understanding of organization in the central research system since the 1950s.

The "data from ICAR" disclosed that only 75% of the total budget of the Indian Agricultural Research Institute was spent on agricultural research (p. A–24). This ratio of 75% is applied to budgets reported by all central research institutes to obtain their research expenditures. But the ratio is not applied to agricultural research stations within the Agricultural Universities.

"(1) The budgets reported by all Research Institutes and Agricultural Universities (*not research stations however*) were multiplied by 0.75 to estimate the research component.
(2) The budgets of agricultural colleges were multiplied by 0.5 to obtain the research component. This was *arbitrary and based on the relatively larger teaching activity in colleges*. In fact, our impression is that these colleges conduct very little research" (Mohan, Jha and Evenson, p. A–24) (emphasis ours).

We may recall here that the 25% share of nonresearch expenditure in the IARI is determined by the large postgraduate and doctoral research programs in the Institute. (The IARI was deemed a university by 1965, and the postgraduate program strengthened with active support from the Rockefeller Foundation since 1958). All other central research institutes had only research functions and some minor research training programs, which would certainly not account for 25% of institute budgets. Thus, the Mohan, Jha and Evenson (1973) estimates for the central research expenditures are underestimates.

The general assumption made to calculate research expenditures by state sector is that a standard ratio is applicable for all SAUs in the country. Thus, budgets of all agricultural colleges are multiplied by 0.5 in Mohan, Jha and Evenson (1973), while Pardey and Roseboom assume that "a third of all state government contributions to the SAUs are spent on research" (Pardey and Roseboom, 1989, p. 229).

Ratio of research to total expenditure varies from one SAU to another (see, ICAR, 1978, Appendix VIII and ICAR, *SAU Information*, 1989). Moreover, when the Mohan, Jha and Evenson estimates were made (until 1968), only seven States in India had agricultural universities with integrated research, education and extension functions. Agricultural colleges under the existing SAUs may have had a certain proportion of resources devoted to research, but in those that were outside the SAU system, it was highly unlikely that research accounted for half of the total budget of the college.

In the ISNAR (Pardey and Roseboom, 1989) series SAU expenditure figures represent only the state government contributions to research (p. 229). In Table A1, a comparison of our state research expenditure (SRE) series with the ISNAR series is given. The observed differences are due to the fact that the ISNAR series assumes a uniform allocation of one-third of total SAU expenditure for research in all states, whereas state-wise research expenditures taking into account organizational changes over time have been estimated in our SRE series.

A comparison of estimates of the Central Research Expenditure (CRE) also reveals differences. (See Table A2) These differences arise from the basic assumptions made by Mohan, Jha and Evenson (1973). The ISNAR estimate for earlier years is based on Mohan, Jha, and Evenson (1973) data, generated using "adjustments" such as budgets of large universities, colleges and institutes rising to their 1968 levels by 1960, and of small institutes maintaining their budget levels of 1968 from the date of establishment. The organizational changes in 1966, severe resource crunch in the central government (reflected in the slump in research receipts both of the ICAR and the Central Ministry of Agriculture) during the early 1960s, and the nearly threefold increase in Central research funding for agriculture between 1966–67 and 1967–68 are ignored (see Mohan, Jha and Evenson, 1973).

Table A1. *Comparison of our SRE estimates and ISNAR estimates (Rs. Lakhs)*

Year	Total Research Expenditure by State Governments: Our estimates	Total Research Expenditure by State Governments: ISNAR estimates	Difference (%)
1975	2105.7	1674.33	20.5
1976	2572.9	2104.50	10.4
1977	2661.5	2534.67	12.3
1980	3725.7	3825.18	2.7
1981	4116.9	4255.34	3.4
1982	4756.4	4685.51	1.5
1983	4851.0	5115.68	5.5
1984	6050.7	5445.85	9.9
1985	7173.2	5976.02	16.7

Source: our estimates and Pardey and Roseboom (1989), p. 229.

Table A2. *Comparison of our CRE estimates and ISNAR estimates (Rs. Lakhs)**

Year	Our estimates						ISNAR estimates
	Ministry of Agriculture				Commerce*	Total	
	Agrl. Res.	Vet Res.	ICAR Res. Payments	Total Agrl.	Coffee + Rubber	Central Research	
1975	0.09	1.95	3050.40	3052.45	49.52	3101.97	4151.41
1976	0.31	2.28	4151.41	4154.00	62.13	4216.14	4881.56
1977	0.33	1.83	4882.00	4884.15	75.56	5035.28	n.a.
1980	0.62	7.14	7474.21	7481.98	134.32	7617.30	9590.00
1981	0.51	4.13	8081.12	8085.75	158.02	8243.78	10180.00
1982	0.24	5.04	9579.06	9584.34	190.15	9774.49	11320.00
1983	0.26	5.09	11076.99	11082.35	236.66	11319.01	11860.00
1984	0.27	4.89	12167.69	12172.85	306.57	12479.42	13440.00
1985	0.25	4.84	14311.32	14316.40	357.34	14673.75	14840.00
1986	0.25	4.84	15172.51	15177.59	504.50	15682.09	15780.00

*Tea is not included here. Ministry of Commerce undertakes tea research only for the north and east. For the entire south, it is handled by the UPASI.
Source: Our estimates, and Pardey and Roseboom (1989), p. 229.

Table A3. *Agricultural research expenditure by the public/joint sector industries (Rs. '000)*

Year	Industry		
	Agrl. Machinery	Fertilizers	Total
1976–77	5.66	267.81	3176.33
1978–79	12.01	355.72	5518.60
1980–81	37.00	456.33	8636.50
1982–83	34.49	583.50	12246.30
1984–85	61.70	688.03	17122.09
1985–86	75.17	716.36	19861.75
1986–87	80.20	985.67	23706.02

Source: DST, *R&D Statistics*, relevant years.