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Johannes Roseboom
Philip G. Pardey

isnar

INTERNATIONAL SERVICE FOR NATIONAL AGRICULTURAL RESEARCH

ISNAR

P.O. Box 93375

2509 AJ The Hague, Netherlands

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**Johannes Roseboom is a research associate at the International Service for National Agricultural Research, ISNAR, The Hague. Philip Pardey is jointly a Senior Research Officer, ISNAR, and Assistant Professor, Department of Agricultural and Applied Economics, University of Minnesota, St. Paul. The authors would like to thank Barabara Craig and Wilhelmina Eveleens for useful comments.

MEASURING THE DEVELOPMENT OF NATIONAL AGRICULTURAL RESEARCH SYSTEMS

Agricultural research is facing new and renewed demands to generate the knowledge and technologies required to sustain productivity growth in agriculture in order to feed and clothe a burgeoning world population. In addition, the increased political awareness of the environmental impacts of agricultural production practices is placing still further demands on national agricultural research systems (NARS) to address such issues. Access to reliable statistics on the state of NARS on a global scale is a prerequisite for sound analysis and informed policy debate. Careful measurement begets reliable statistics. It is our purpose in this paper to describe the on-going efforts at the International Service for National Agricultural Research (ISNAR) to compile and maintain a set of global indicators of NARS in both the more- and less-developed countries.

Background

ISNAR's mandate is to assist less-developed countries with policy, management, and organizational issues related to agricultural research, thereby placing it in a unique position to monitor the development of NARS throughout the world. The organization's frequent contacts with a wide range of less-developed country NARS is helpful but far from sufficient to ensure that the global policy analysis and policy making community have access to reliable measures of current agricultural research capacity on an international, regional or national scale, let alone meaningful indications of such developments over time. The disparate and often conflicting information that is generally available must first be synthesized into a meaningful set of statistics before a global overview of NARS is possible.

Some five years ago ISNAR began the process of developing and maintaining a set of basic statistics on NARS with an emphasis on compiling annual, national-level, research expenditure and personnel data. The resulting ISNAR Indicator Series, as reported in Pardey and Roseboom (1989), represents a fully documented and sourced compilation of data on NARS in 154 more- and less-developed countries, where possible, for the 27 years 1960 through 1986. Our initial efforts entailed a complete recompilation of existing data sets such as those by Boyce and Evenson (1975), Judd, Boyce, and Evenson (1983 and 1986), and Oram and Bindlish (1981). These series were then integrated with new data obtained from three primary surveys carried out by ISNAR -- one at a global level and the other two targeted to the Pacific and West Asia & North Africa regions respectively -- plus data drawn from a review of over 1000 documents which included published papers, monographs, country reports, and a substantial amount of unpublished grey literature. A concerted effort was made to ensure that a consistent and comparable institutional coverage was maintained both within a country, over time, and among countries.

We placed a premium on compiling an historical rather than simply a contemporaneous set of agricultural research indicators. Agricultural research is appropriately seen as an investment activity. Research eventually leads to an increase in the stock of knowledge or an improvement in technology, which in turn generates a stream of future benefits that continues until the new technology or knowledge is superseded or becomes obsolete.

But, for agricultural research to realize its growth promoting impacts takes some time. There are lags in the research process itself (Pardey 1989) and further lags in the uptake of new technologies and new ideas (Lindner 1981; Tsur, Sternberg, and Hochman 1990). As a result, the productivity effects of research can persist for up to 30 years (Pardey and Craig 1989). Thus, relatively long time series of research expenditure and personnel data are required if they are to be of help in informing policy makers on the efficacy of alternative research investment portfolios and institutional arrangements.

Defining a NARS

Before quantifying the capacity of a NARS in terms of expenditures and number of researchers employed, it was necessary that we developed a precise idea of what, in fact, was being measured. The NARS concept in general use by ISNAR and others, while useful for some conceptual and policy purposes, is of limited value for statistical purposes. In system theory language it is a *soft system* concept, that is to say it is an abstract idea which can help bring order to a complex and obscure reality. A source of considerable confusion, however, is that this abstract notion of a system is "... used in everyday language in an unreflecting way as if it were a label word for an assumed ontological entity, like 'cat' or 'table'. We casually speak of 'the education system', 'the legal system', 'the health care system', ... ['the national agricultural research system'], as if all these were, unproblematically, systems" (Checkland 1988). In order to move beyond the inherently soft system characteristic of a NARS, we chose to give some statistically meaningful precision to the concept by dissecting a NARS into its three dimensions namely (a) national, (b) agricultural and (c) research, and to consider each of these dimensions separately.

National

The notion of what constitutes a "national" set of statistics on agricultural research is open to many interpretations. One option is to adopt a geographic interpretation and include all agricultural research --be it in the public or private sector-- performed within the boundaries of a country. Another possibility is to pursue a sectoral approach and include domestically targeted research activities funded and/or executed by the public sector of a particular country. This latter approach was adopted for the Indicator Series, which attempts to include all agricultural research activities that are financed and/or executed by the public sector, inclusive of private, nonprofit agricultural research. It explicitly excludes private, for-profit agricultural research. This sectoral coverage corresponds to that adopted by the OECD (1981, 83-91) and includes the government, private nonprofit, and higher-education sectors, but excludes the business-enterprise sector.

The government sector was taken to include those federal or central government agencies, as well as provincial or state and local government agencies, that undertake agricultural R&D. One must be careful to avoid double-counting federal resources that fund agricultural research at the state or provincial level, and ensure that nonresearch activities are excluded such as rural extension.

The private, nonprofit sector generally includes only a small number of institutions, which are nevertheless, very important for some countries. Some commodity research in less-developed countries, particularly that concerned with export-oriented estate crops such as tea, coffee, and rubber, is often financed wholly or in part by (industry-enforced) export or production levies and performed by private or semiprivate nonprofit research institutions. These institutions often operate as pseudo-public-sector research agencies or, at the very least substitute directly for such agencies, and therefore are included as public agricultural research.

The higher-education sector is fairly readily identified but does present special problems when agricultural research statistics are compiled. Care was taken to isolate research from nonresearch activities (e.g., teaching and extension) and to prorate personnel and expenditure data accordingly.

The national agricultural research statistics reported in the Indicator Series excluded the activities of research institutions with an international or regional mandate, such as CIMMYT, IRRI, and WARDA, along with ORSTOM and CIRAD. While their research output may often have substantial impact on the agricultural sectors of their host countries, their mandates direct their research activities towards international and regional, rather than national applications. However, all foreign research activities that are either funded or executed in collaboration with the national research agencies (or administered by them) were included in the series.

Agricultural

When measuring science indicators by socioeconomic objective, the OECD (1981, 113) recognizes that two approaches are possible. They can be classified

a. according to the *purpose* of an R&D program or project;
b. according to the general *content* of the R&D program or project.

For example, a research project to improve the fuel efficiency of farm machinery could be placed under "agriculture" if classified by purpose, but "energy" if classified by R&D content. The Indicator Series adopted the procedure used by the OECD and classified research by purpose rather than content, as it is generally the purpose for which research is undertaken that has the greatest relevance for policy.

The definition of agricultural research used for the Indicator Series includes research in primary agriculture (crops, livestock, plus factor-oriented topics) as well as forestry and fisheries. In general terms, this corresponds with the coverage used by both OECD (1981) and UNESCO (1984). For policy and analytical purposes, it would be desirable to differentiate agricultural research among commodities, but the way most agricultural research expenditure and personnel data are reported makes it an unsurmountable task at a global level.

A further difficulty is that a significant amount of agricultural research has an effect at the postharvest stage, while the technology is embodied in inputs that are applied at the farm level. Take, for example, the efforts of plant breeders to improve the storage life of horticultural crops or to alter the baking quality of cereals. These characteristics are embodied in new crop varieties that are adopted by farmers. Furthermore, there is a lack of uniformity in the way research that is applied directly at the postharvest stage is currently reported. The OECD (1981, 115) classification omits "R&D in favor of the food processing and packaging industries" from their socioeconomic objective of *agriculture,* *forestry and fisheries*, while UNESCO (1984, 64) includes "R&D on the processing of food and beverages, their storage and distribution." The Indicator Series sought to implement a variant of these approaches, excluding, where possible, research applied directly at the postharvest stage. Omitting research on food processing and packaging improves the compatibility of these statistics with value-added measures such as agricultural GDP and the like. Nevertheless, public sector research targeted directly to food and beverage storage (and in some cases, processing) may in practice be included in this series, although this is more likely to be true of advanced systems in the more-developed countries.

A final difficulty was to obtain statistics for the higher-education sector, classified by purpose or "socioeconomic objective." The more general case is to find personnel and, possibly, expenditure data, classified by field of science, where the basis of classification is the nature rather than the purpose or objective of the research activity itself. In those cases where it was necessary to rely on field-of-science data, the series attempted to follow the UNESCO (1984, 77) procedure and consider agronomy, animal husbandry, fisheries, forestry, horticulture, veterinary medicine, and other allied sciences, such as agricultural sciences, thereby excluding fields such as bacteriology, biochemistry, biology, botany, chemistry, entomology, geology, meteorology, zoology, and other allied sciences. These latter fields are more appropriately classified as natural sciences, although in some cases the classification is a little hazy. It was therefore necessary to apply a "purpose or objective test" to some of these so-called natural science disciplines and to include in the series research undertaken in these areas when the ultimate purpose or objective of that research could have a direct impact on the agricultural sector.

Research

It is possible to identify a continuum of research from basic, or upstream, research to applied, or downstream, research. Much agricultural research has been characterized as mission-oriented in the sense that it is problem-solving, whether or not the solution to the problem requires basic or applied research. OECD (1981, 28) states that "the basic criterion for distinguishing R&D from related activities is the presence in R&D of an appreciable element of novelty." For instance, monitoring the incidence of plant and animal diseases is not considered research if it is only undertaken to enforce quarantine regulations or the like. But, using this information to study the causes or control mechanisms associated with a particular disease is considered research. Of course, some screening of the literature, newly available plant and animal material, and alternative production practices should be included as research, where this is used to adapt existing agricultural technology to local conditions.

Agricultural research includes a significant amount of maintenance research that attempts to renovate or replace any deterioration in gains from previous research. Gains in output are often subject to biological degradation as pests and pathogens adapt to research-conferred resistance and control mechanisms. The role of maintenance research is substantial not only in many more-developed countries where current production practices employ technologies that are biologically intensive, but also in many less-developed countries, particularly those situated in the tropics where relatively rapid rates of pest and pathogen adaptation tend to shorten the life of research-induced gains.[1]

The difficulties of differentiating research from nonresearch activities is especially pertinent in the case of agricultural research, given the dual role of many public-sector agencies charged with agricultural research responsibilities. It is common to find such agencies involved in additional nonresearch activities such as teaching; extension services; certification, multiplication, and distribution of seeds; monitoring and eradicating plant and animal diseases; health maintenance (involving veterinary medicine activities distinct from research); and analysis and certification of fertilizers. In general, it is separating the research component from the joint teaching-research activities (in the case of universities) and the joint extension-research activities (of ministerial or department-based agencies) that is most difficult. If direct measures of expenditure and personnel data were not available at the functional level, then secondary data were often used to estimate the appropriate breakdown of aggregate figures into their research versus nonresearch components.

Even in the case of those institutions whose mandate is ostensibly limited to research, there were problems in obtaining consistent coverage of research-related activities. For example, general overhead services, including administrative personnel or expenditures required to support research, can be excluded from reported figures for a variety of reasons. In some instances, the institutional relationship between a national research agency and the ministry within which it is located means that overhead services and the like are charged against the ministry and not the research agency. Alternatively, some research agencies report total personnel and expenditure statistics based on an aggregation of project-level rather than institution-level data. In such cases, administrative overheads may not be allocated across projects and thus omitted entirely or in part from the agency-level statistics.

A further issue involved identifying the research component of the farm operations that are usually undertaken in support of agricultural research. To the extent that such farm operations are necessary to execute a program of research, it seems appropriate that they be included in a measure of the commitment of national resources to agricultural research. However, some systems undertake farm operations at levels well above those required to support research, with the surplus earnings from farm sales being siphoned off to support research and even various nonresearch activities. In some instances, including all the resources devoted to the farm operations of a NARS substantially overstates the level of support to agricultural research within the system.

There was also the need to make a clear distinction between economic development and experimental development. According to OECD (1981, 25), "experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience that is directed to producing new materials, products, or devices, to installing new processes, systems, and services, or to improving substantially those already produced or installed." Experimental development is therefore concerned with applying new findings from formal and informal research activities. This contrasts with the notion of economic development, which in general terms, is concerned with improving the well-

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[1] Recent evidence (Adusei and Norton 1990) suggests that the US devotes around a third of its total agricultural production research to maintenance work.

being or standard of living of members of a society in a particular country or region.

Clearly, while improvements in agricultural productivity that follow from experimental development contribute to the process of economic development, they represent only part of the story. Improvements in rural infrastructure, via investments in irrigation, transportation and communication facilities plus improved rural health and education services, also contribute to the economic development of the agricultural sector and, ultimately, to society as a whole (Antle 1983).

A problem arises when one attempts to compile statistics on agricultural research and experimental development activities in less-developed countries. A substantial portion of R&D activity is financed and/or executed as part of an economic-development aid package. It is often difficult to identify the experimental versus economic-development component of an aid package, particularly given the project orientation of much development aid. For instance, development assistance to establish, upgrade, or rehabilitate irrigation facilities can often incorporate research to evaluate water quality and identify preferred crop varieties as well as agronomic and irrigation practices. However, including all of the project's resources in a measure of NARS capacity could seriously overestimate the level of resource commitment to agricultural research.

Another less obvious difficulty concerns the somewhat transient nature of some of the agricultural research funded through development projects, which tends to be of relatively short duration (one to five years). In some cases it is undertaken largely by expatriates and is never a part of the existing national research infrastructure. This type of research presumably contributes to the overall level of national research activity and should be captured in a NARS indicator, particularly if one is concerned with measuring sources of growth or technical change within a country. However, to the extent that such research is not integrated into the existing national research infrastructure, it is not a good measure of the "institutionalized research capacity" of a national system. The strategy pursued in this case was to include such development-financed research only when the research component could be isolated from the nonresearch component with an acceptable level of precision, and when it appeared to be integrated into the existing agricultural research infrastructure within a country.

Translation Procedures

Compounding the difficulties of simply measuring agricultural research expenditures is the need to translate these value aggregates reported in current local currency units into some comparable real value or implicit volume measures. There are two practical methods for deriving research volume measures, namely:

(a) first convert the local currency values into US dollars and then apply an appropriate US price index to account for price level variability;

(b) first deflate the local currency values using appropriate price indices which account for temporal variability in local price levels and then convert into a constant US dollars using some base year measure of relative currency values.

The choice of an appropriate local price index entails some conceptual difficulties. Readily available price indices are typically general indices that may not reflect price developments in specific sectors or components (such as agricultural research) of an economy. Another problem is that price indices are commonly constructed using fixed quantity weights, as in a Laspeyres price index. The advantage of these measures is their ease of interpretation; they tell us how much the cost of purchasing exactly the same basket of research inputs has changed over time. Their disadvantage lies in the fact that they tend to overstate changes in the general price level by failing to allow for changes in the composition of the basket of research inputs which are likely to occur if there are changes in *relative* prices over the period being considered. The longer the time horizon of the study, the more likely it is to understate the volume of research inputs by deflating with a fixed weight index that fails to account for substitution. As argued in the index number literature, the use of chained (Divisia) price indices which incorporate rolling price weights would alleviate this last problem. However, in an international context, these indices are so rarely constructed, if ever, that they are currently not an option for international comparative analysis.

There are numerous deflators and currency converters that can be incorporated into either of the translation procedures described above. Unfortunately, the choices matter. Since we have no independent measure of the truth, we are forced to proceed using some rules of thumb.

In choosing a price deflator, one should use the price index that most nearly reflects the composition of the research aggregate to be deflated. In multicountry studies, this rule of thumb will argue for an algorithm in which value aggregates are deflated first with a local price index whenever adequate price indices are available for each country in the sample. The basket of research inputs covered in a local price index may be quite different from that of a numeraire country's index when living standards and local relative prices vary substantially across the countries in a sample. This cross-sectional variability would lead to biases in measurement whose direction and magnitude would be difficult to predict.

A more subtle problem is the combined choice of deflator and converter. If the values to be compared are the total values of a single uniform good, the two algorithms (deflation then conversion or conversion then deflation) yield the same result if and only if the deflator and converter are defined over the specific good. If the values to be compared are aggregates -- as they are in our case -- the deflator and the converter must be defined over the specific basket of inputs represented by the aggregate. General price indices, market and/or official exchange rates, and nonspecific purchasing power parities[2], PPPs, all introduce biases to the extent that they reflect aggregates whose composition may differ from the research input aggregate of interest.

Even with properly defined deflators and converters, the problems of aggregation cannot be escaped. As demonstrated in Pardey, Roseboom, and Craig (forthcoming) the two algorithms will yield different volume series unless it is the scale and not the composition of the research aggregates that varies over time and across countries. Both algorithms diverge from the desired volume measure as the composition of the research aggregate changes across the sample. When using the convert-first procedure, the volume measure

[2]Purchasing power parities, by definition, measure the local cost of buying a bundle of goods and services in a particular country at its own prices relative to the corresponding cost in, say, dollars for the same bundle in the US.

will be biased unless the composition of the numeraire country's aggregate is representative of all other countries in all years of the sample. The deflate-first procedure will generate biases in the volume measure whenever the base-year basket of research inputs within each country is not representative of that country for the period being considered.

So, in a particular application, the choice of algorithm must be made on the basis of whether it is the temporal or cross-sectional composition of the research aggregate that is likely to vary most. Researchers have shown a preference for converting local currencies to dollars first and then deflating using a US price index. However, in a data set that includes countries at diverse stages of development, it is quite likely that cross-country differences in the composition of the research aggregates will dominate the temporal variability unless the data span several decades; hence, a deflate-first procedure would demand far less of the data.

Table 1 reports research volumes resulting from the application of a deflate-first procedure using two alternative currency convertors. For this application, no price index covering the specific mix of labor, materials, and equipment peculiar to agricultural research was available in each country, so the implicit GDP deflator was a practical compromise. The annual average exchange rate (AAER) used was the yearly official market rate, which generally corresponds to the IMF's *rf* or inverted *rh* rate. The PPP series, which was defined over GDP, represented another compromise. Published PPPs either cover too few countries or a basket of goods that is not particularly representative of agricultural research. The commodity coverage of PPPs obtained from the Summers and Heston (1988) used here did, at least, correspond closely to that of the implicit GDP deflators being used.

Table 1: *Regional Volumes of Agricultural Research Resources; Alternative Measures*

Region	Deflate first and convert with 1980 annual average exchange rates		Deflate first and convert with 1980 purchasing power parity indices	
	(millions 1980 dollars)	%	(millions 1980 PPP dollars)	%
Sub-Saharan Africa (43)[a]	373	5.3	372	5.0
Asia & Pacific (28)	522	7.5	1160	15.5
Latin America & Caribbean (38)	480	6.9	709	9.5
West Asia & North Africa (20)	342	4.9	455	6.1
Less-Developed Countries (129)	1718	24.6	2696	36.0
More-Developed Countries (22)	5273	75.4	4785	64.0
Total (151)	6991	100.0	7481	100.0

Source: Annual average exchange rates and implicit GDP deflators are primarily taken from World Bank (1989), PPPs from Summers and Heston (1988), and agricultural research expenditures from Pardey and Roseboom (1989).

[a]Figures in brackets represent number of countries.

Across the two procedures the global volume of resources committed to agricultural research on an annual basis averaged over the 1981-85 period varies by approximately

$500 million. Differences across translation methods at the regional level are even more dramatic -- especially for the less-developed countries. In particular the Asia & Pacific region almost doubles its share of the global volume of research resources if PPPs rather than AAERs are used as currency convertors. This can be traced to the fact that relative price levels in less-developed countries, and in particular those in the Asia & Pacific region, as reflected in Summers and Heston's (1988) PPPs, are lower on average than those implied by market exchange rates.

Figure 1a: *Percent deviation of convert-first from deflate-first formula using AAER converters and implicit GDP deflators (Base-year = 1980)*

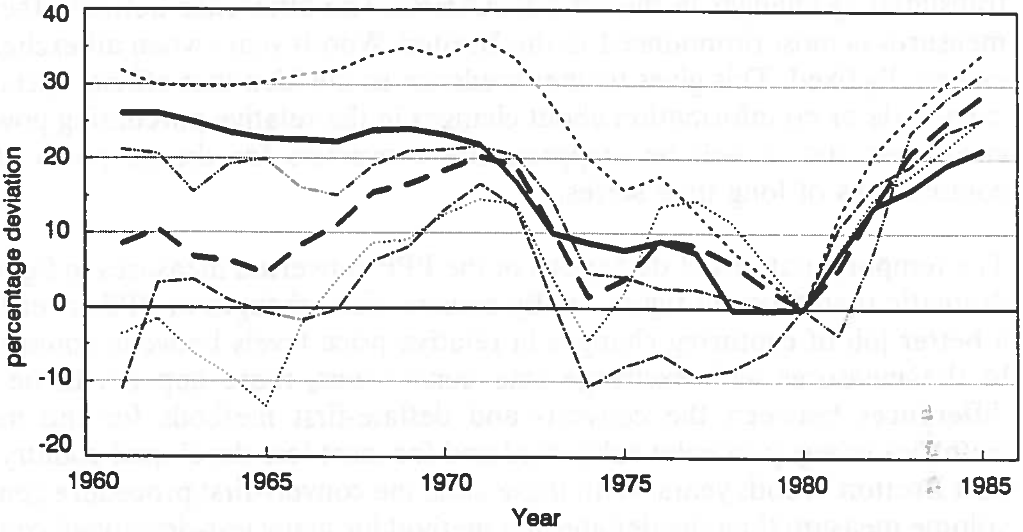
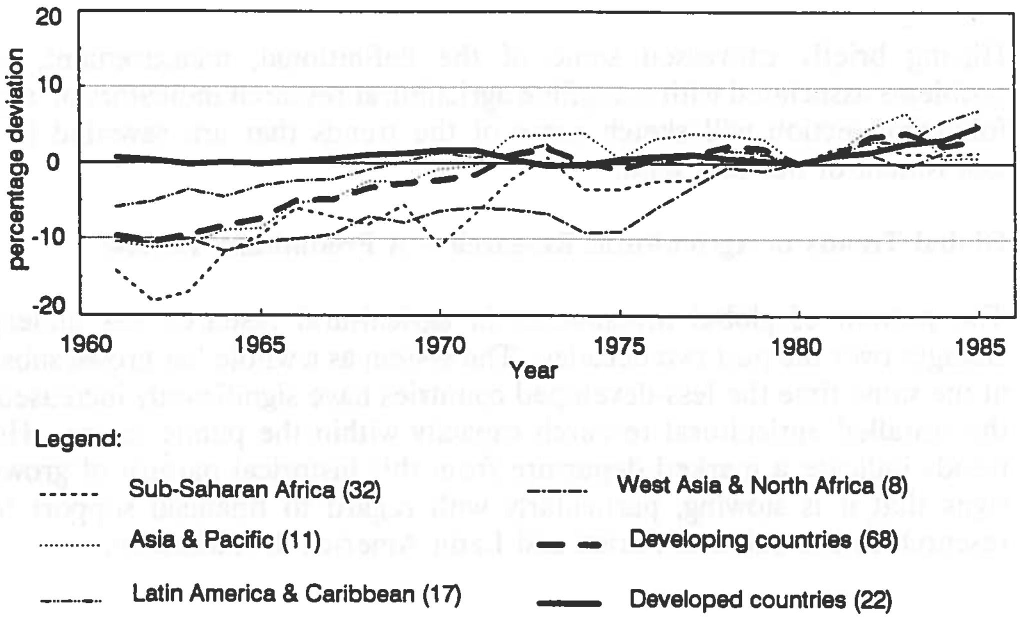


Figure 1b: *Percent deviation of convert-first from deflate-first formula using PPP convertors and implicit GDP deflators (Base-year = 1980)*



As previously mentioned the choice of algorithm is also important; particularly over longer periods of time and when AAERs are used. Figure 1a presents the percent deviation of the deflate first versus the convert first volume measures when annual average exchange rates and implicit GDP deflators are used to derive the respective volume measures. In figure 1b the same graph is presented for the volume series which used PPP exchange rates and GDP deflators.

When AAERs are used, the deflate-first algorithm led to a consistently larger volume measure than that obtained when expenditures were converted first. This suggests that, ceteris paribus, either the US dollar was undervalued with respect to virtually every country's currency in 1980, or that movements in local price levels were imperfectly translated by changes in the official AAERs. The difference between these two volume measures is most pronounced in the Bretton Woods years when all exchange rates were essentially fixed. This gives further credence to the idea that official exchange rates may carry little or no information about changes in the relative purchasing power of different currencies and so will be inappropriate converters for the purposes of international comparisons of long time series.

The temporal pattern of deviations of the PPP converted measures in figure 1b is far less dramatic than those in figure 1a. By construction, changes in PPPs over time should do a better job of capturing changes in relative price levels between countries. In contrast to the measures with exchange rate conversions, there appears to be no systematic differences between the convert- and deflate-first methods for the more-developed countries in any particular subperiod and for most less-developed country regions in the post Bretton Woods years. With these data, the convert-first procedure generates a larger volume measure than the deflate-first method for many less-developed country groupings during the Bretton Woods years. It is difficult to make too much of this trend as pre-1975 PPPs for many of the less-developed countries were derived using so-called short-cut extrapolation methods based, among other things, on market exchange rates without the benefit of local price measures based on benchmark survey data (Summers and Heston 1988).

Having briefly canvassed some of the definitional, measurement, and translation problems associated with compiling agricultural research indicators on a global scale the following section will sketch some of the trends that are revealed by a preliminary assessment of our new data.

Global Trends in Agricultural Research -- A Preliminary Review[3]

The pattern of global investments in agricultural research has undergone dramatic changes over the past two decades. The system as a whole has grown substantially, while at the same time the less-developed countries have significantly increased their share of the installed agricultural research capacity within the public sector. However, recent trends indicate a marked departure from this historical pattern of growth -- there are signs that it is slowing, particularly with regard to financial support for agricultural research in sub-Saharan Africa and Latin America & Caribbean.

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[3]The data presented in this section is preliminary in nature and currently undergoing final revision for inclusion in Pardey, Roseboom, and Anderson (forthcoming).

Table 2: *Agricultural Research Personnel and Real Expenditures (regional totals)*

Region	1961-65	1966-70	1971-75	1976-80	1981-85
	Agricultural Researchers (full time equivalents)				
Sub-Saharan Africa (43)[a]	1,323	1,841	2,416	3,526	4,941
Asia & Pacific (28)	6,641	9,480	12,439	18,559	22,576
Latin America & Caribbean (38)	2,666	4,122	5,840	6,991	9,000
West Asia & North Africa (20)	2,157	3,485	4,746	6,019	8,995
Less-Developed Countries (129)	12,787	18,929	25,440	35,095	45,513
More-Developed Countries (22)	41,297	44,424	47,726	51,253	56,233
Total[b] (151)	54,084	63,353	73,167	86,348	101,745
	Agricultural Research Expenditures (1980 PPP dollars, millions)				
Sub-Saharan Africa (43)[a]	149	227	277	359	372
Asia & Pacific (28)	317	475	651	928	1,160
Latin America & Caribbean (38)	229	355	487	679	709
West Asia & North Africa (20)	127	250	301	341	455
Less-Developed Countries (129)	822	1,307	1,716	2,308	2,696
More-Developed Countries (22)	2,191	3,057	3,726	4,172	4,785
Total[b] (151)	3,013	4,365	5,442	6,480	7,481
	Real Expenditure per Researcher (1980 PPP dollars)[c]				
Sub-Saharan Africa (43)[a]	113,000	123,400	114,600	101,800	75,300
Asia & Pacific (28)	47,700	50,100	52,400	50,000	51,400
Latin America & Caribbean (38)	85,900	86,200	83,300	97,200	78,800
West Asia & North Africa (20)	58,800	71,700	63,400	56,700	50,600
Less-Developed Countries (129)	64,300	69,100	67,400	65,800	59,200
More-Developed Countries (22)	53,000	68,800	78,100	81,400	85,100
Total[b] (151)	55,700	68,900	74,400	75,000	73,500

Source: Pardey and Roseboom (1989), and preliminary data from Pardey, Roseboom, and Anderson (forthcoming).

[a]Bracketed figures represent number of countries in the regional totals.
[b]World totals which, due to data limitations, excludes USSR, Eastern Europe, China, Mongolia, North Korea, Vietnam, Cambodia, Djibouti, Bhutan, South Africa and Cuba.
[c]Figures represent weighted averages rounded to the nearest hundred dollars.

Research Personnel

Averaging over the 1981-85 period, the global total[4] of agricultural researchers working in the public sector stood at just over 100,000 full time equivalent researchers (table 2). This represents a 1.9 fold increase in the number of public sector agricultural researchers

[4]Countries excluded from the totals reported in this paper are detailed in the notes to table 2.

since the 1961-65 period which translates into an annual growth rate of 3.2%. Over this same period the number of researchers grew in a fairly uniform manner across all the less-developed regions at almost four times the rate (6.3%) than it did for the more-developed countries (1.6%). As a result the global share of researchers in less-developed countries increased from 24% in 1961-65 to 45% in 1981-85 (figure 2a). In 1981-85 the Asia & Pacific region accounted for 49% of the less-developed country total in table 2, with around 20% of the less-developed country researchers residing in both the Latin America & Caribbean and West Asia & North Africa regions, and the remaining 11% in sub-Saharan Africa. By including South Africa in these regional figures the number of researchers in the sub-Saharan 1981-85 total reported in table 2 increases by around 39% and more than doubles the number of scientists in the region who hold a post-graduate degree.

Figure 2a: *Agricultural researchers, regional shares*

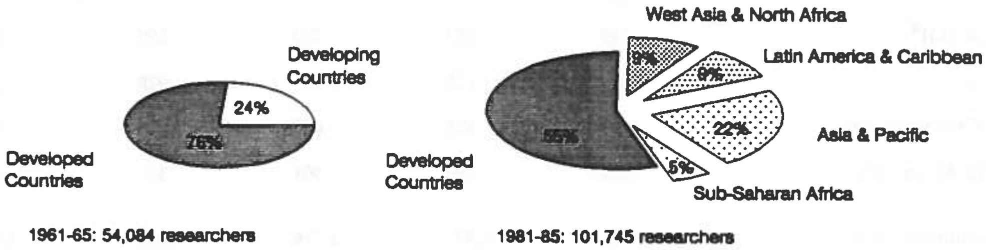
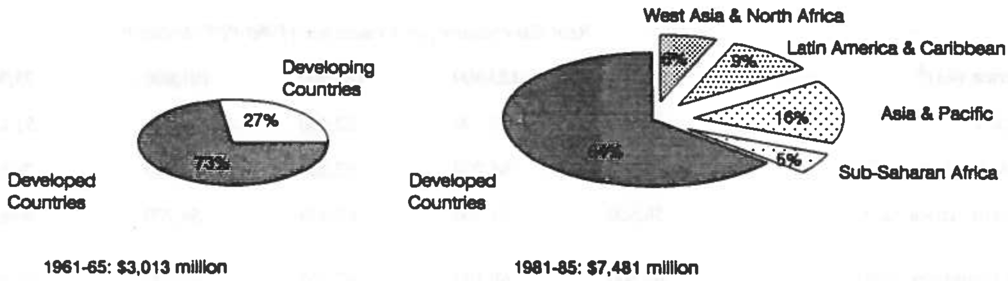


Figure 2b: *Agricultural research expenditures (1980 PPP dollars), regional shares*



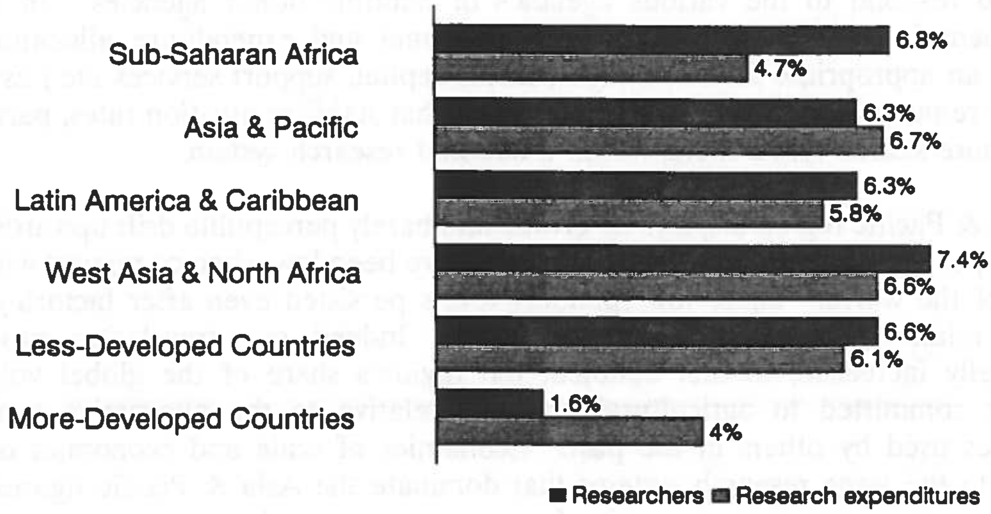
Research Expenditures

Global spending on public agricultural research averaged $7.5 billion in 1981-85, up by a factor of 2.5 (compared with 1.9 for research personnel) on the global level of real expenditures just two decades earlier. The less-developed countries expenditure share grew from 24% in 1961-65 to only 35% in 1981-85, considerably less than the corresponding fraction of the world's agricultural researchers (45%) employed by the public sectors of the less-developed countries (figure 2b).

Comparative patterns of growth in research personnel and expenditures are presented in figure 3. While the 6.1% rate of increase in real spending for less-developed countries as a group was approximately 50% larger than real spending increases for the more-developed countries over the 1961 to 1985 period, it fell marginally short of the 6.6% increase in research personnel experienced by the less-developed countries over the corresponding period. By contrast, the more-developed countries, as a group, increased their real expenditures at approximately double the rate of their research personnel.

A closer study of the period-to-period averages in table 2 reveals a general contraction in financial support for agricultural research in the less-developed countries during the latter period of the sample. The precipitous decline in the rate of growth in real spending for sub-Saharan Africa over the last period in our sample reflects a widespread slow down throughout the region compounded by a 23% decline in total spending by the Nigerian system, which alone accounts for approximately one quarter of public spending on agricultural research in all of sub-Saharan Africa. Anecdotal evidence suggests this contractionary pattern of support for public sector agricultural research has continued or even accelerated over the more recent past for many less-developed countries and may even have spread to some of the more-developed countries as well.

Figure 3: *Annual average growth of research personnel and expenditures, 1961-65 to 1981-85*



Spending per Scientist

Regionally comparative indicators of real expenditures per researcher are also presented in table 2. With real expenditures measured in 1980 PPP terms, the overall spending per scientist ratio for more-developed countries increased steadily from $53,000 in 1961-65 to $85,100 in 1981-85. Thus, the more-developed countries as a group moved steadily towards more capital intensive -- both human and physical -- research systems over the past two decades. Evidence based on detailed data from the US state agricultural experiment stations on the changing factor mix of their research systems points to a significant increase in human rather than physical capital over the longer run. By contrast, the less-developed countries spent $64,300 per researcher in 1961-65 -- some 21% more per researcher than the more-developed countries for the same period -- which peaked during the early to mid-1970s, followed by a steady decline to $59,200 by the 1981-85 period. Moreover the pattern of growth in spending per scientist ratios among less-developed countries is rather uneven.

The overall decline in labor productivity and at best stagnation in land productivity that characterizes sub-Saharan agriculture since the early 1970s somewhat belies the growth distortionary government policies that accelerate the transfer of resources out of agriculture and bias public sector infrastructural investments in favor of urban as opposed to rural areas have played a role here as elsewhere. However the sustained and substantial decline in spending per scientist ratios observed since the early 1970s -- and which during the last period in our sample spread to 65% of the region's NARS -- may provide clues to some additional causes of this productivity paradox. For one, the rapid growth in the region's researcher cadre has been realized through large increases in the number of relatively inexperienced, and hence less expensive, nationals. Expatriate ratios have dropped from approximately 90% in the early 1960s to around 29% in the 1981-85 period, with the limited evidence available suggesting that during this latter period 60% of the region's researchers had less than 6 years research experience. Moreover, the region's NARS are especially reliant on donor sourced funds -- our estimates placing the donor share during 1981-85 at around 36% -- and as a consequence staffing decisions have a tendency to be decoupled from expenditure decisions. Personnel decisions are made largely within the context of a domestic policy environment often constrained by civil service regulations while expenditure levels, and equally importantly research priorities, must also respond to the various agenda's of multiple donor agencies. In such an environment it is difficult to harmonize personnel and expenditure allocations that maintain an appropriate factor mix (i.e., labor, capital, support services etc.) as well as desirable remuneration and incentive structures that stabilize attrition rates, particularly for the more skilled researchers, within a national research system.

The Asia & Pacific region displays an erratic and barely perceptible drift upwards in real spending per researcher levels that historically have been low when compared with other regions of the world. These low spending levels persisted even after factoring in the region's relatively low average price levels. Indeed our translation procedures substantially increased, in fact doubled, the region's share of the global volume of resources committed to agricultural research relative to the alternative translation procedures used by others in the past. Economies of scale and economics of scope accruing to the large research systems that dominate the Asia & Pacific figures would tend to lower average costs per unit of research output and in turn account, to some extent, for the region's lower spending per researcher ratio. In addition, relatively lower labor service costs, resulting from a comparative abundance of labor, would induce a substitution of labor for capital and other inputs in the knowledge production process, to also drive down the region's spending per scientist ratio.

Average spending per scientist ratios for the Latin America & Caribbean region as a whole were relatively stable over the 1961-75 period, increased during the late 1970s (mainly due to the larger South American NARS) and declined throughout the region in the early to mid 1980s. This decline was driven as much by stagnating expenditure levels as it was by a relatively rapid growth in research personnel which, given the current austerity measures facing many countries in the region, will pose continuing problems for these NARS.

Support for NARS

Securing and maintaining domestic political support for the public sector component of NARS and translating that into financial support for agricultural research is a fundamental issue confronting all national research policy makers. Agricultural research intensity (ARI) ratios that express expenditures on public sector agricultural research as a proportion of agricultural product (AgGDP) are commonly cited measures of the support afforded NARS. The data in table 3 shows an approximate doubling of ARI ratios for both less- and more-developed countries alike over the 1961 to 1985 period. This data also confirms the positive correlation between income levels and ARI ratios noted by earlier observers, with ARI ratios for high income countries more than double those of low- and middle-income countries.

Table 3: *Agricultural Research Intensity and Relative Research Expenditure Ratios*

	Agricultural Research Intensities[b]			Relative Research Expenditures[c]
Income Class[a]	1961-65	1971-75	1981-85	1981-85
Low (29)[d]	0.30[e]	0.40	0.66	8.5
Lower-middle (28)	0.49	0.69	1.00	9.5
Middle (18)	0.47	0.58	0.84	8.7
Upper-middle (18)	0.59	0.82	1.26	8.3
Low and middle (93)	*0.45*	*0.60*	*0.91*	*8.8*
High (16)	1.03	1.82	2.37	11.3
Total (109)	*0.49*	*0.69*	*0.85*	*9.2*

Source: Pardey and Roseboom (1989); and preliminary data from Pardey, Roseboom, and Anderson (forthcoming).

[a]Countries assigned to income classes based on mid-period, 1971-75, per capita GDP averages where: Low, < $600; Lower-middle, $600-1500; Middle, $1500-3000; Upper-middle, $3000-6000, High, > $6000.

[b]Agricultural Research Intensities (ARI) ratios measure agricultural research expenditures as a proportion of AgGDP.

[c]Relative Research Expenditure (RRE) ratios measure agricultural research expenditures as a proportion of government expenditures on agriculture. These ratios include 19 low, 20 lower-middle, 13 middle, 16 upper-middle and 12 high income countries. This particular series is definitely provisional and will be subject to further revisions.

[d]Bracketed figures represent number of countries in each income class.

[e]All figures represent simple averages across all countries in each income class.

However, as Pardey, Kang, and Elliott (1989) observed, a potentially more instructive approach to understanding the structure of support for agricultural research is gained by placing publicly funded research in the context of the overall level of public support for agriculture. The relative research expenditure (RRE) ratio in table 3 represents the proportion of total public expenditure on agriculture spent on agricultural research. It thus provides an indication of the *relative* importance given to research on agriculture within the constraints imposed by overall public spending on agriculture. Clearly the income linked pattern of support for agricultural research that many have implied from an inspection of ARI ratios is far less evident in the RRE data. While cognizant of the general assertion that governments in low-income countries tend to discriminate against agriculture (while high-income countries discriminate in favor of agriculture) our data, at least for the present, leaves open the question of whether or not policy makers in poor as opposed to rich countries give a *differential* (i.e., lower) level of priority to agricultural research within the overall constraints of spending on agriculture. More fundamental limitations to increased public support for research in low income countries may well lie in the financial and political constraints imposed by overall and agricultural-specific levels of public sector spending. Certainly much more analysis is needed if we are to understand the (political economy) forces that shape the support for NARS and give policy guidance that duly recognizes such constraints.

Summary Remarks

Over the last five years a small team at the International Service for National Agricultural Research, ISNAR, The Hague, has been working to establish a global database on national agricultural research systems. The database contains a fully sourced and extensively documented set of research personnel and expenditure indicators for NARS in 154 more- and less-developed countries for the 27 years 1960 through to 1986, where possible. The series was reported in a volume by Pardey and Roseboom published in October 1989.

In addition to the conceptual and practical difficulties of measuring the capacity of a NARS and of maintaining consistency of coverage over time and across countries, a major measurement issue involves the translation of research expenditures expressed in current local currency units into a constant (i.e., base year) numeraire. The findings on alternative translation procedures presented here have relevance not only for our own work but for all international comparison work. We experimented with alternative translation procedures and demonstrated that the choice of procedure matters, particularly for the less-developed countries. Our preferred approach suggests that the *real volume* of resources committed to research in less-developed countries is substantially greater than that obtained using conventional translation procedures.

The preliminary assessment of our data shows a rapid expansion of the capacity of NARS over the period 1961-65 to 1981-85. Less-developed country NARS grew on average more rapidly than more-developed country NARS. In many less-developed country NARS, however, the number of researchers has increased at a greater rate than real expenditures. As a consequence spending per researcher across less-developed countries has declined steadily since the early 1970s -- in contrast to a sustained increase in spending per scientist in the more-developed countries since the beginning of our sample (1961) -- particularly in sub-Saharan Africa, West Asia & North Africa and, of late, in Latin America.

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